The WELDING JOURNAL

NOVEMBER 1951

IN THIS ISSUE

Welding Fixtures for Use with Submerged Arc 977
The Inert-Arc Welding of Thin-Walled Tubing 986
Wage Incentives 992
Pressure Welding 995
Resistance Variations in Spot Welding 1004
Seam Welding of Monel Metal 537-s
Graphitization of Clad Vessels 544-s
Buckling of Intermittently Supported Plates 546-s
Properties of Metals Used at Low Temperatures 572-s
Effects of Plastic Strain and Heat Treatment 576-s
Table of Contents 975
Index to Advertisers 1033

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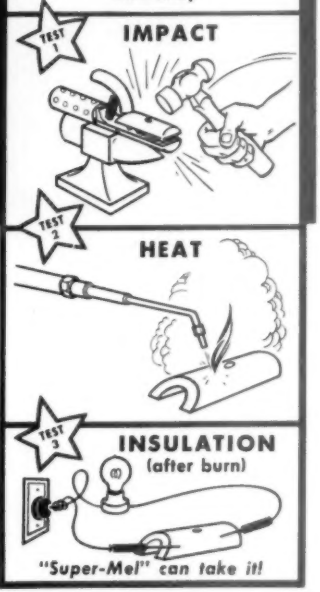

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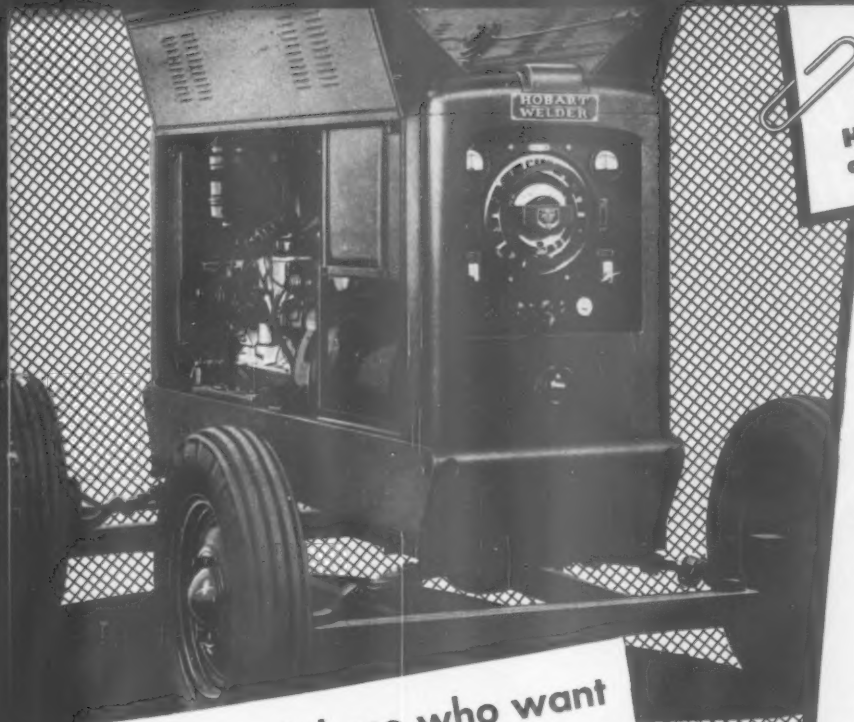

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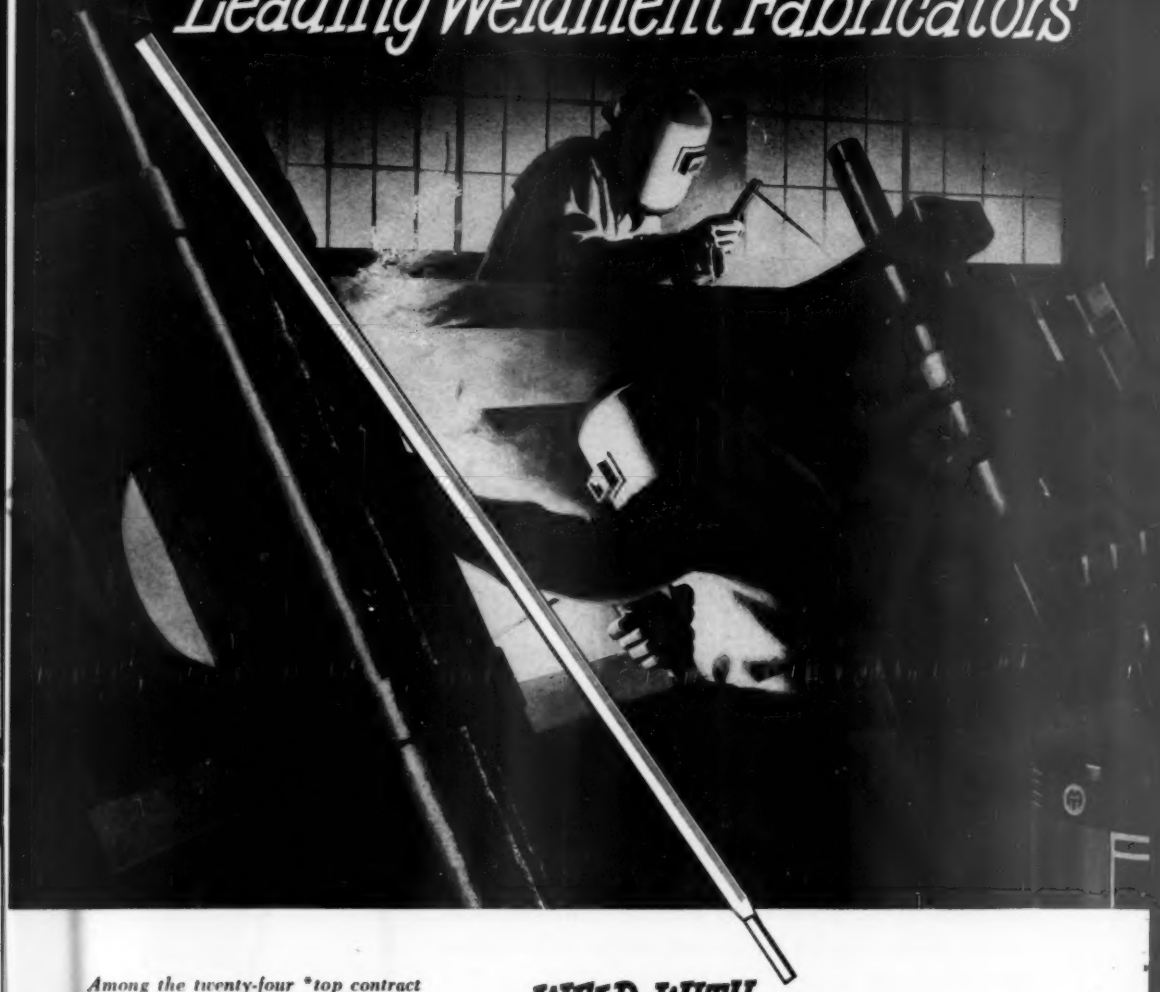

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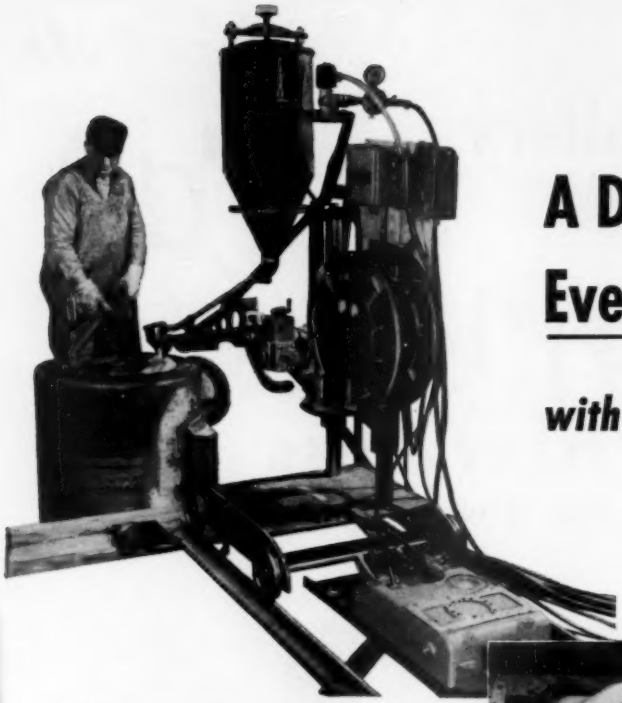

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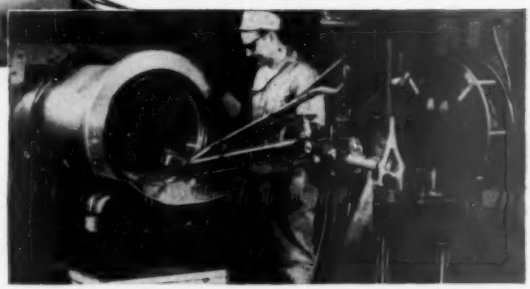

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TECHNICAL PAPERS, ITEMS AND REPORTS

Welding Fixtures for Use with Submerged Arc, by John Berkeley 977

The Inert-Arc Welding of Thin-Walled Tubing, by R. S. Zeno and H. L. C. Leslie 986

Wage Incentives, by J. N. McClain 992

Pressure Welding, by Frank S. Gardner 995

Current Welding Literature 1003

Resistance Variations During Spot Welding, by W. L. Roberts 1004

Safe Practice in Oxyacetylene Welding and Cutting, by Simon A. Greenberg 1020

PRACTICAL WELDER AND DESIGNER

Good Welding Setups, by James E. Dipert 1026

Giant Size Hex Nuts Flame-Cut with Ease from 24-in. Billets 1028

Cadmium Fume Hazard 1029

Practical Heating Tricks, by F. C. Geibig 1030

SOCIETY AND RELATED EVENTS

Society News 1032

Index to Advertisers 1033

Personnel 1041

Employment Service Bulletin ... 1046

New Products 1048

News of the Industry 1057

New Literature 1060

List of New Members 1061

Section Activities .. 1062

Abstracts of Current Welding Patents 1066

WELDING RESEARCH SUPPLEMENT

Seam Welding of Monel Metal, by Ernest F. Nippes and Gerald M. Slaughter 537-s

Statement on the Occurrence of Graphitization in Carbon Steel of Stainless-Clad Vessels 544-s

Buckling of Intermittently Supported Rectangular Plates, by C. H. Norris, D. A. Polychrone and L. J. Capozzoli 546-s

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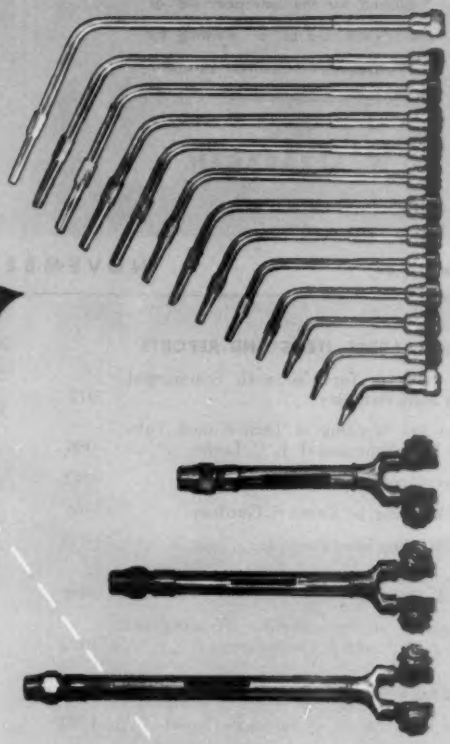

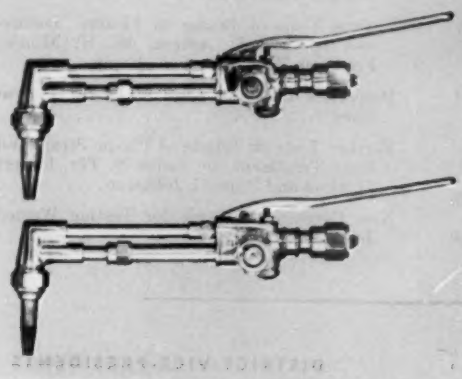

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The WELDING JOURNAL

volume 30 November 1951 number 11

Welding Fixtures for Use with Submerged Arc

Successful use of automatic welding requires efficient deposition of flux, disposal of the slag, recovery of unfused material, adequate backing and suitable fixtures for the techniques employed

by John Berkeley

SUBMERGED arc welding has opened a broad field for improved methods in the fabrication of welded parts. The process has been well received by industry because excellent welds at a low unit cost can be made with a relatively small capital investment. As a consequence, automatic welding has had a constantly expanding field of application. The diversified use of this process at the present time is due to a large extent to the development of a number of new types of welding fixtures. These fixtures are designed to meet the problems inherent in production submerged-arc welding.

The successful and economic use of automatic welding requires the consideration of several factors. Efficient means to deposit flux, dispose of the slag, and recover the unfused material must be provided. Adequate backing is required if full penetration is desired. The backing may be afforded by the workpiece itself, or by some type of chill bar in the fixture. The edges of the work should fit up well to avoid burning through, and they should be clamped securely. The work must be clean and oil-free if sound welds are to be made. Finally, the process is so fast that loading and unloading time becomes a large factor, particularly on small work. The closer a welding sequence approaches a continuous arc, the more efficient the fixture.

These considerations indicate that the design of a welding fixture is closely related to the design of the workpiece and to manufacturing techniques utilized prior to welding. Any fixture requirement, therefore, is met by balancing a number of elements, one against another. In addition to the shape of the workpiece and type of seam, these elements are: total production quantities, desired daily production, allowable cost of the fixture, and features involving the physical plant layout and production facilities.

Two more components influence the design of welding fixtures for submerged arc. First, workpieces are of such divergent nature that standard fixtures are the exception rather than the rule. To a large extent, the best a designer can do is to combine standard machine elements in various ways to meet individual situations. Second, the field is new, and there is no large backlog of previous experience and common practice upon which to draw. Each new workpiece is likely to pose a problem for the designer because he may be working in territory which has not previously been explored.

The design of welding fixtures, for the above reasons, is a field of great latitude. There can be more than one solution for any welding problem, and a machine designed to fit one set of conditions will not necessarily be suitable for another. The balancing of the various factors of fixture design frequently is an undertaking of some consequence, and simple clamps and fixtures rarely can be used successfully to obtain maximum economy. As a result, submerged-arc fixtures are tending to become more complete and complex. There is great emphasis upon automatic cycling. The fixtures constitute a new family of machines. In essence, they are machine tools of a specialized nature. They can be called machine fixtures.

The wide diversity and overlapping in welding fixtures makes it difficult to set up an empirical outline which defines the many types of machines in use. Basically, however, they can be divided into two major categories—those machines designed for welding circumferential seams, and those designed for longitudinal seams.

The fixtures used to illustrate this paper have been chosen because they are representative examples of the major types of machines in each of the two categories. Salient features of the design and purpose of the machines will be discussed.

John Berkeley is an Engineer with The Berkeley Equipment Co., Danville, Ill.

Paper presented at the Thirty-Second Annual Meeting, A.W.S., Detroit, Mich., week of Oct. 15, 1951.

CIRCUMFERENTIAL-SEAM WELDERS

Machines for holding and turning workpieces with circumferential seams can be divided into five types. Each type includes a number of variations.

Turning rolls
Spindle drive fixtures
Internal chucking fixtures
External chucking fixtures
Turntables

Turning rolls, in their simplest form, are paired rolls, usually faced with rubber. The pairs of rolls often are laterally adjustable so that various diameters of work can be handled. They should be turned by an adjustable speed drive. The set of rolls shown in Fig. 1 is an application which is more versatile than the average installation. An air-actuated kicker facilitates loading. The rolls, driven by a variable-speed hydraulic motor, are mounted on trucks which travel along a track. Longitudinal travel is provided by a long hydraulic cylinder fixed to one of the trucks.

Fig. 1 Powered turning roll trucks with work ejectors

This set of rolls is one of the few automatic welding fixtures capable of handling both circumferential and longitudinal seams. Used as simple turning rolls, this fixture is adapted principally to welding girth seams on large tanks. Its use as a longitudinal welder will be discussed later.

Turning rolls require an additional fixture to carry the welding head. Figure 2 is a jib suitable for this purpose. It has powered vertical travel, and the boom can rotate 360 degrees on a ball thrust bearing. A common application with this type of fixture is to serve a set of turning rolls on one side and a positioner on the other with the same welding head. The welding head is carried on a truck fitted with ball bearings. Variable speed travel along the boom can be provided, and a jib thus equipped is suitable for welding longitudinal seams.

Standard turning rolls generally are not suited for high-production work, but they can be incorporated in the design of fixtures so that a high degree of efficiency is obtained. Figure 3 illustrates a special-purpose machine fitted with turning rolls. This fixture is designed for welding several seams on tank wheels, one of which can be seen in place on the fixture. The machine

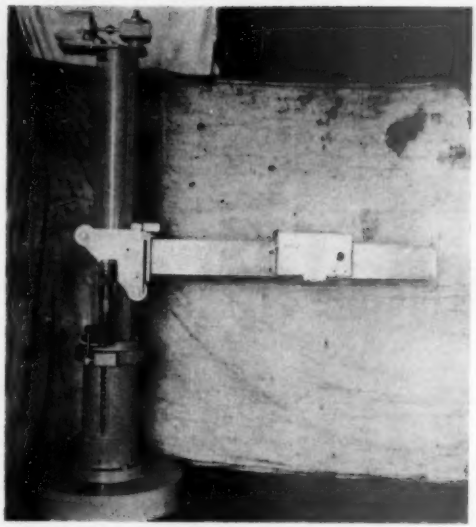

Fig. 2 Universal jib fixture for carrying welding head

consists of an idling central spindle upon which the wheel is carried. The serrated turning rolls are hardened steel insulated from the drive spindles by fiber bushings. The rolls are turned by double-reduction worm gearing which is driven by a variable-pitch V-belt sheave. The welding head is carried by two air-hydraulic cylinders. A cam-operated slide makes it possible to introduce the welding nozzle into the hole in the wheel and move it into position to make a weld behind the overhanging lip of the hole. Flux is picked up at two points in this application. Excess flux which

Fig. 3 Wheel welder with work supported on turning rolls

is not picked up by the nozzle behind the welding head spills into a hopper. The hopper is fitted with baffles and a screen to separate the slag from the granular flux.

This machine is arranged for automatic sequence. After the piece is loaded, the operator presses the start button and the weld cycle starts. The air-actuated central spindle lifts the wheel off the wear strips on the face of the machine, the welding head is lowered into position, the work is rotated and the weld is made. A timer stops the weld, the head is retracted, the spindle lowers the work onto the wear strips and the cycle is complete.

Spindle-drive fixtures are illustrated by Figs. 4 and 5. The standard application consists of a driven headstock and a clamping tailstock. In both these machines, an air cylinder with a live center in the piston rod serves as the clamping means. Figure 4 is the left-hand unit of a pair of machines set up to weld crawler-tractor wheels. The hinged bracket on the loading carriage supports an asbestos dam, which retains a sufficient depth of flux on the small-diameter work. The welding head is retractable so that the welding area is clear for loading. The headstock spindle is fitted with an ejector mechanism which moves the work clear of the spindle nose when the weld is completed and the tailstock is withdrawn. The loading carriage is equipped with wheels to follow this motion. A feature of this machine is a vibrating flux screen actuated by an eccentric mounted on the motor shaft. This screen separates unfused flux from slag. A variable-speed hydraulic motor drives the headstock spindle through two worm-gear reducers.

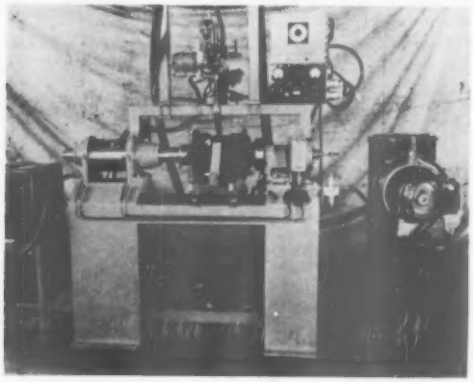

Fig. 4 General purpose spindle type fixture for circumferential seams

Figure 5 shows a multiple head setup. The loading mechanism in this application consists of two rack-and-pinion-driven plungers which lift the work off the slide bars to the spindle center line. Flux overflow runs into two hoppers, from which it is sucked back into the overhead collectors. Grounding is accomplished in a similar manner on all machines of this nature. In this instance, the ground consists of a bronze shoe in contact with the headstock spindle.

The spindle-drive-type of machine fixture can be adapted for a wide range of work. Various types of centers, clamping jaws, ejectors and locating rings can be used, and variations in length can be accommodated by mounting the tailstock on a slide, similar to the construction of a lathe.

Internal chucking fixtures are distinguished from other spindle-drive machines by the absence of a tailstock. They are particularly useful in the welding of large-diameter work, or work with a wide swing such as the axle shown in Fig. 6. The machine illustrated has a hollow spindle which carries an internal expanding chuck powered by air. A mechanical loader can be added to a fixture of this type quite readily, because of the clear access to the spindle.

External chucking fixtures are not as common as

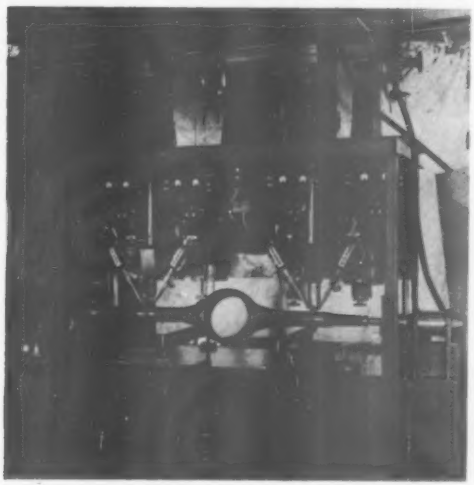

Fig. 5 Multiple head weld on truck axle

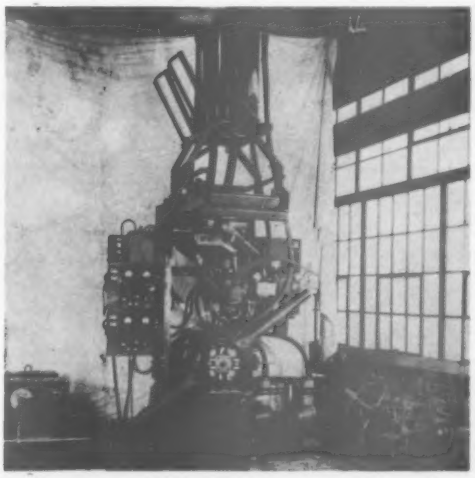

Fig. 6 Multiple head weld on truck axle. Internal chuck type fixture

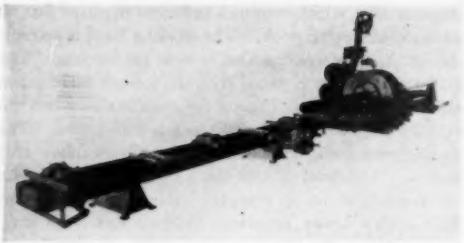

Fig. 7 Special machine for butt welding two lengths of heavy pipe

other type of rotary machines. The application shown in Fig. 7 was designed to round up and hold large-diameter pipe for butt welding. The machine consists of two heavy hydraulic chucks set side by side. The chucks rest on and are turned by driven rolls. A length of pipe is fed through the chucks and over the boom at the far end of the machine. Another length of pipe is fed into the near chuck. The work is clamped up, rounded and aligned exactly by the chucks, which are of fifty-ton capacity in this application. Backup for the weld is provided by a copper shoe mounted at the end of the boom. The close-up (Fig. 8) shows the shoe, and also the cam which engages a limit switch to control the weld cycle. The conveyor drive for this machine is of interest. It consists of a pneumatic tire mounted on a swinging arm. When in working position, it slides the pipe over special rolls, which are designed to allow free motion in two directions.

It will be noted that external and internal chucks can be mounted on spindle-drive fixtures and turntables, in addition to being types of rotary fixtures in themselves. This points up the similarity in basic nature of rotary fixtures, and the infinite variations possible in machine-fixture design.

Turntables are the commonest type of rotary fixture. The standard universal positioner is the type most frequently seen. In many cases, a standard positioner can be adapted to production welding quite readily, but many other production problems require fixtures of a more specialized nature in order to realize maximum economy. Figure 9 is an example. The machine consists of a light-duty positioner with a hollow spindle. An air-operated locating and clamping mandrel is fitted into the spindle. The workpiece is set in the locating fingers on the turntable, the boss to be welded is slipped over the nose of the spindle, a clamping pin is inserted in the end of the mandrel, air is applied and the boss is clamped tightly against the body of the work-piece. When loading and unloading, the welding head is swung out of the way manually. The pillar which supports the welding head is movable to allow adjustment for work of various sizes. Flux is recovered in the pan mounted across the front of the machine. This is the simple stand cheapest method of flux recovery, and it is entirely satisfactory for many applications where the added expense of an automatic flux recovery unit is not warranted.

Figure 10 illustrates an adaptation of the same basic

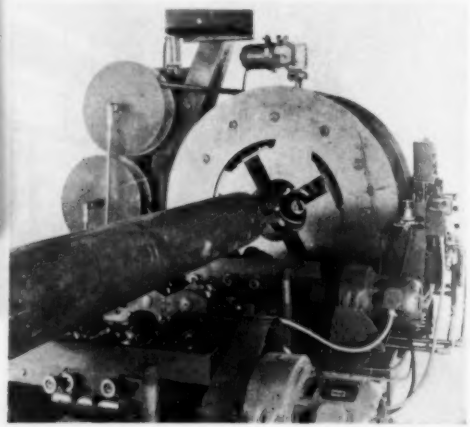

Fig. 8 Close-up of external hydraulic chuck for pipe butt welder

Fig. 9 Special purpose positioner

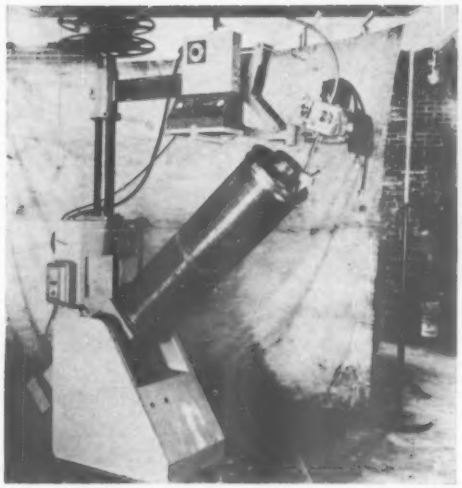

Fig. 10 Special purpose positioner

turntable for a long workpiece. In this instance, it is necessary to swing the welding head out of the way when raising and lowering the work. This is accomplished by an air-actuated parallel motion. As in Fig. 9, the position of the welding head can be changed to suit work of different size. The example shown is another automatic cycling setup, in which the operator starts the cycle and the weld is completed, with the work piece returned to loading position automatically.

An interesting example of a turntable machine fixture is shown in Fig. 11. This four-station machine is designed to make short circumferential welds in a nearly continuous cycle. Each of the small turntables is a station in the progress of the weld cycle—dump flux, weld, recover flux, and load and unload. Each of the small turntables is driven by a planet gear engaging an internal sun gear. As the large turntable rotates, therefore, the small tables are driven at the chosen welding speed. The welding head rotates through a 90-degree arc at the same rate of progress as the large turntable. At the end of each weld, the head swings back to starting position, where it meets the next workpiece, and the cycle continues as long as desired. High-frequency starting of the arc is necessary in this application.

This machine represents the latest thinking in automatic production welding, and is an example of the successful welding of very short seams.

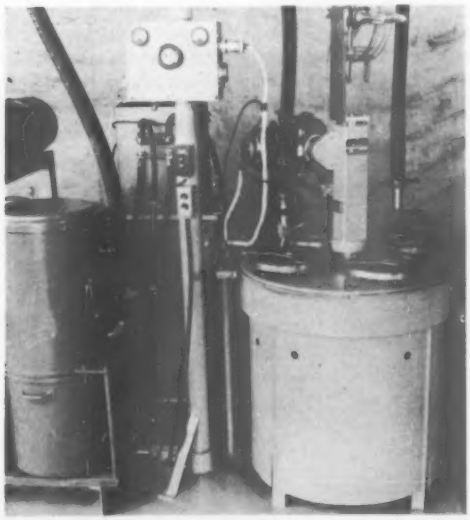

Fig. 11 Automatic sequence, multistation girth seam welder

LONGITUDINAL-SEAM WELDERS

Machines for holding or moving the work and welding longitudinal seams can be divided into five types.

Travel carriages
Stake or horn jigs
Boom-type fixtures
Continuous mills
Rotary fixtures

Travel carriages are a basic mechanism for the welding of longitudinal seams. The most satisfactory type is a self-contained motorized unit with infinitely variable speed which is driven along a track by a positive drive such as a rack and pinion. The carriage and track alone can be used to weld a wide variety of work, especially weldments of large size. This fundamental type of setup, however, does not lend itself to high production without the addition of other elements.

Figure 12, for example, is an illustration of a travel carriage and beam with a work-holding trough. The application shown in the photograph is a good example of the versatility of submerged arc-welding fixtures. The machine is designed for building up worn crawler-tractor links, an operation which requires precise control of the weld. As the travel carriage moves along the beam, the dwell, length of free travel and length of weld are controlled by a series of cams mounted behind the

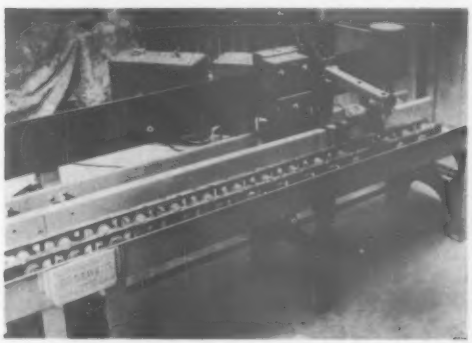

Fig. 12 Fixture for metal overlay on crawler tracks

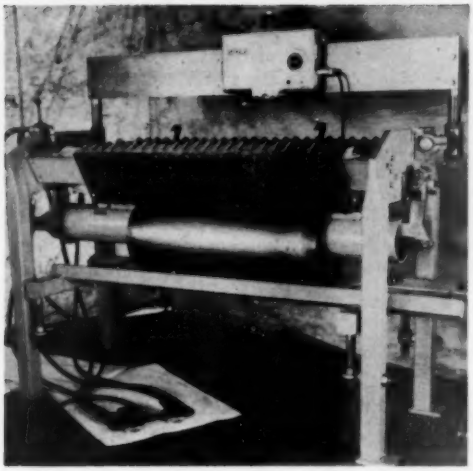

Fig. 13 Stake fixture for longitudinal welds—beam clamping type

carriage track. The cams can be set so that any desired combination of weld and travel can be obtained. In operation, the work is completely covered with flux.

A broad range of work can be handled in a trough fixture of this kind. The backup beam, visible just behind the crawler track, can be used to clamp up many types of flat work. The beam is moved in and out by a rack-and-pinion mechanism to bear against work of different widths.

Stake, or horn-type fixtures also incorporate a travel carriage and track in their design. Figure 13 illustrates a recent development in this type of fixture. The individual clamps are actuated by fire hose. They are set at a sixty-degree included angle so that the clamping action tends to force the edges of the work together while holding them against the backup shoe in the mandrel. The seam edges are lined up square with the

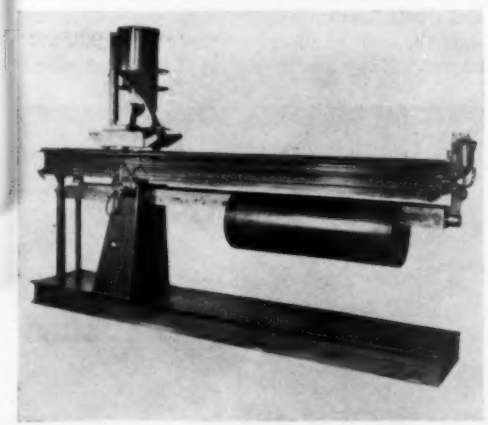

Fig. 14 Stake fixture for longitudinal welds—mandrel clamping type

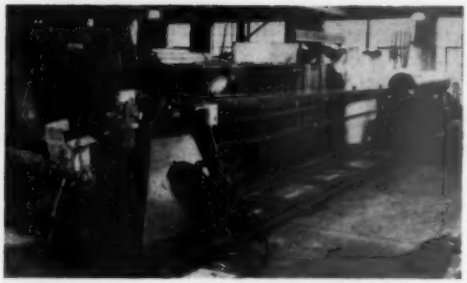

Fig. 15 Boom welder for internal longitudinal seams

line of travel by two knife-edged dogs, which are swung clear during welding. The mandrel is water cooled, and an air-actuated toggle clamp holds the end against the clamping pressure.

Another style of stake fixture is shown in Fig. 14. The principal difference between this fixture and the one described in the preceding paragraph is that, in this design, the clamping jaws are stationary, and the clamping pressure is supplied by fire hose laid beneath the backup bar.

The stake fixture is well adapted for certain kinds of work. It is not a high-production machine, when compared to a tube mill, because loading and clamping take an appreciable amount of time.

Boom-type fixtures are used for inside-seam welding on pipe or tanks. Figure 15 shows a typical setup, which incorporates the turning rolls described earlier (Fig. 1). The welding head is mounted at the rear of the boom, and the wire is carried to the nozzle at the front through a tube (Fig. 16). The work is carried over the boom by the roll trucks, driven by a hydraulic cylinder, the speed of stroke being set by a flow-control valve. The weld is followed, in this application, by watching the hot spot at the weld point through a mirror. Adjustments to maintain the seam under the arc are made by inching the turning rolls in the required direction. A variation of this method of seam following is to actuate the nozzle instead of the work.

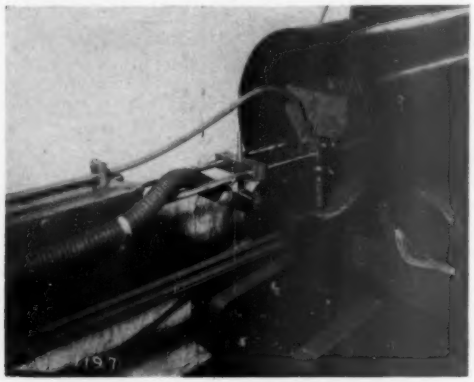

Fig. 16 Close-up-nozzle end of boom welder

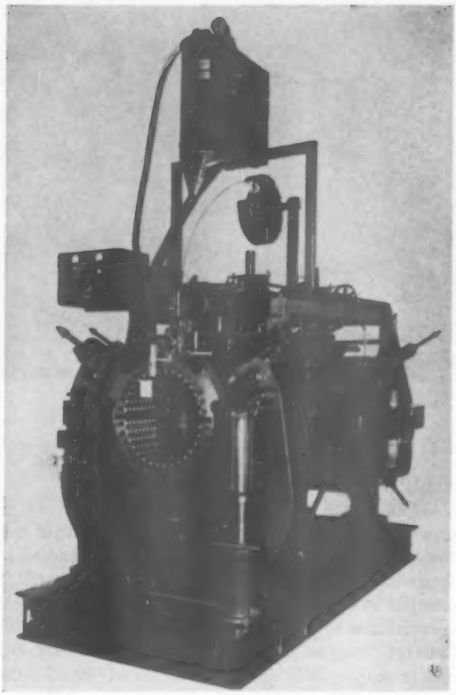

Fig. 17 Continuous tube mill-12 in.–14 in. capacity

Continuous tube mills are the highest capacity machines for longitudinal welding. The machine shown in Fig. 17 is designed for work from 12 to 24 in. in diameter. It is capable of handling pieces as short as 3 ft. and ranging in thickness from 16 gage to $^{3}/_{8}$ in. The work is loaded at the rear of the machine, over a mandrel which is suspended from thin stainless steel fins (Fig. 18). It is driven into the closing die, or cage, by a series of knurled or serrated rolls. The cage, at the front end of the machine, contains a large number

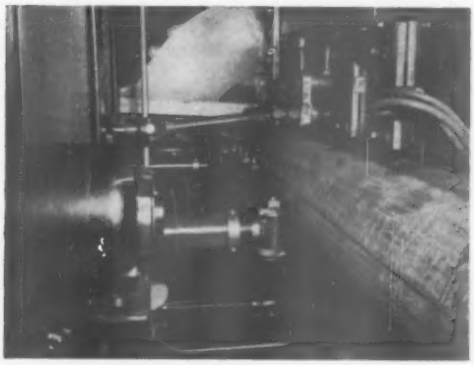

Fig. 18 Close-up of mandrel—continuous tube mill

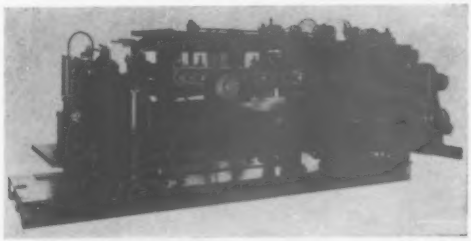

Fig. 19 Heavy duty tube mill arranged for twin arc

of small rolls. It is made in three segments, the lower of which is closed against the work by hydraulic pressure supplied by an air-hydraulic intensifier. The front end of the mandrel, inside the cage, carries a metal chill bar which is water cooled. Flux is deposited immediately behind the welding head and is picked up by a vacuum unit a short distance in front of the head. The weld is continuous, and once in operation, the machine can run off miles of pipe or tubing without interruption.

A heavy-duty machine of the same type is illustrated in Fig. 19. This application is designed for twin arc, and has a pipe feeder added at the entrance end, and two cages, or closing dies, at the front. The feeder mechanism consists of two sets of opposed, rubber-faced hourglass rolls.

Figure 20 shows a different type of tube mill. This machine has a capacity of 16 to 42 in. diameter, and a thickness of $^{1}/_{2}$ in. The main point of difference between this mill and the preceding design (Fig. 19) is in the cage. The cage of this machine consists of two sets of steel disks which carry hydraulic cylinders and mechanical jacks. Very heavy closing pressures are possible with this design.

Since all tube mills have a fixed center line, when different pipe sizes are handled at the same conveyor level, it is necessary to raise and lower the machine. The installation in Fig. 20 is raised and lowered in a pit by eight mechanical jacks.

Rotary fixtures for longitudinal welding are high-production, multistation machines such as the plowshare welder illustrated in Figs. 21 and 22. This machine is arranged for automatic sequence welding, so that the

Fig. 20 42-in. Tube mill installation

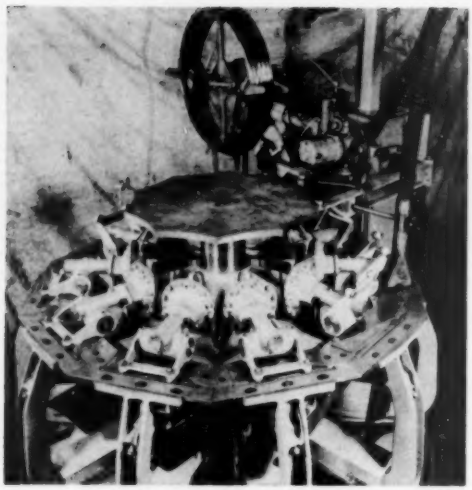

Fig. 21 Top view—10 station plowshare welder

principal duty of the operator is to load and unload the work.

The plowshare welder is driven by a variable-speed V-belt drive to a double-reduction worm-gear reducer which engages a bull gear on the spindle. The various clamps are air-operated and are controlled by solenoid valves. Flux overflow falls into the pan, where it is swept around to an outlet by a scraper. The gearing is protected from the flux by a labyrinth baffle.

It is necessary to cam the welding head so that it follows a straight line relative to the work. On this machine, the head is mounted on a roller-bearing carriage which rides on a square hardened steel track. Wire is carried with the head.

This type of fixture occupies an analogous position in the welding of longitudinal seams that the four-station turntable (Fig. 11) represents in the welding of circumferential seams. It is an advanced type, designed to exploit the advantages of submerged-arc welding to the fullest extent.

DESIGN CONSIDERATIONS

The machine fixtures which have been presented are typical of the major types now in use. They range in complexity from simple turning rolls to large and heavy tube mills, and from manual operation to automatic sequence. All of them, however, have a point in common. It is necessary that they be tools of considerable precision, because welding conditions must be duplicated exactly from piece to piece if uniform results are to be achieved. Consequently, spindles, gearcases, cylinders, bedplates and other major parts must be made with machine-tool accuracy. One of the principal failings in "homemade" fixtures is their inability to perform consistently due to lack of precise workmanship. A solution to a welding problem may be well

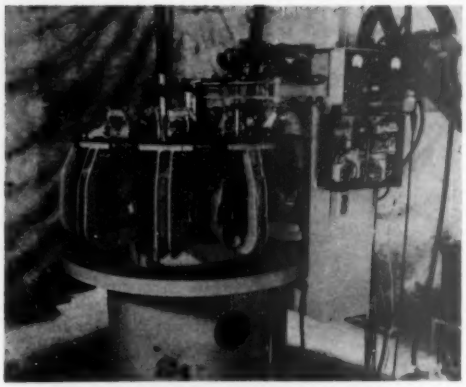

Fig. 22 Side view—plowshare welder

conceived, but it still may fail if the fixture will not exactly duplicate its movements each cycle.

An important design consideration is that welding fixtures frequently operate in adverse conditions of flux, dirt and grinding dust, and they may be handled by men who are not particularly good mechanics. It is essential to guard vital operating parts from dirt, and essential also to make the design as simple as possible. Rolls operating on a track, for example, are less susceptible to scoring and galling than are closely fitted slides, even though they may be somewhat less accurate.

Most machine fixtures are of welded construction. Not only is this cheaper and stronger for a given weight than cast iron, but it is nearly mandatory because of the extremely diversified nature of the equipment which must be built to handle the many welding problems. On the other hand, many of the standard elements of the fixtures described in this paper are cast. Small gearcases, headstocks, air cylinder heads and other items of a similar nature are well adapted to cast construction, by reason of size, shape, production quantities, ease of machining and the production setup in the plant of the manufacturer.

The principal factor in the design of a machine fixture for a given job is the allowable cost of the equipment. This, in turn, is predicated on the type of weld to be made and the nature of the workpiece, the production schedule, and the total quantity of work in sight. If production requirements are small, an expensive automatic fixture is not indicated. Even though production may be large, and a very complete type of machine is best for the job, a point is reached beyond which the design should not go. As often as not, complicated appurtenances are a waste. As a general rule, the best design for a machine fixture contains the fewest number of links, slides, stops and other accessories. However, important production aids such as loaders and flux separators should not be omitted purely for the sake of simplicity.

Many types of drives are used in machine fixtures. Except for single-purpose applications where the weld-

ing speed has been accurately determined, the drive should be of the infinitely variable type. V belts, hydraulic transmissions and friction-drive transmissions all can be used successfully.

Flux pickup is best handled by one of the several vacuum units on the market. While such units are not an absolute necessity in many applications, the over-all economy they provide makes their inclusion in a machine fixture design desirable. On many jobs it also is advantageous to separate unfused flux from the slag by some sort of selective screening.

Features of backup for the weld, loading, wire support and welding head support vary greatly from one machine to another. They are considerations which are modified by the type of workpiece and by the over-all design of the machine.

CONCLUSION

Welding fixtures for use with submerged arc have been a large factor in the widespread application of the process to workpieces which formerly were welded by hand. They can be classified as follows:

Fixtures for circumferential seams
- Turning rolls
- Spindle-drive fixtures
- Internal-chucking fixtures
- External-chucking fixtures
- Turntables

Fixtures for longitudinal seams
- Travel carriages
- Stake or horn fixtures
- Boom-type fixtures
- Continuous mills
- Rotary fixtures

This classification is empirical, and there is overlapping from one type of machine to another. In addition, each of the types of fixtures can be subdivided into a number of styles, each adapted to meet individual welding problems with the maximum economy. It is generally true that single-purpose fixtures, designed for specific workpieces, perform most economically. For this reason, the basic standard types take many forms.

Conditions for automatic welding must be carefully controlled in the interests of uniformity and quality. Fixtures designed for use with submerged-arc, therefore, should be made with precision. As a result, the new machine fixtures have much in common with machine tools, and their precise performance has led to greatly increased production of many products. As new variations of the basic machine fixtures are developed, the area of submerged-arc welding will constantly expand. The possibilities appear to be unlimited.

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REQUIRED BY THE ACTS OF CONGRESS OF AUGUST 24, 1912, AS AMENDED BY THE ACTS OF MARCH 3, 1933, AND JULY 2, 1946

OF THE WELDING JOURNAL, published monthly at Easton, Pa., for October 1, 1951.

State of New York } ss.
County of New York }

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The Inert-Arc Welding of Thin-Walled Tubing

Techniques for inert-arc welding of thin-walled tubing made of stainless steel, mild-steel, nickel, titanium, molybdenum and fernico

by R. S. Zeno and H. L. C. Leslie

Abstract

The inert-arc welding of the following materials was investigated:

(*a*) Type 347 stainless steel.
(*b*) A nickel.
(*c*) L nickel.
(*d*) S.A.E. 1020 steel.
(*e*) Ductile titanium.
(*f*) Molybdenum.
(*g*) Fernico.

Particular emphasis was given to the joining of very thin tubing.

Eight hundred samples in six different joint designs were welded with a special machine built around a Hardinge lathe. The welding variables investigated were as follows: type of current, type of gas, gas flow, type of electrode, arc length, arc current, arc voltage, air eddy currents, travel speed, cleanliness of joint, joint fit, joint design, cleanliness of electrode and method of starting arc. As a result of this investigation the following conclusions appear to be warranted:

1. All the materials investigated are weldable by the inert-arc process.

2. Proper joint fit-up is one of the most important factors in obtaining a strong, leaktight joint. Wherever possible a press fit is recommended.

3. The joint should be free of grease, oil and dirt. A vapor-phase degreasing agent such as trichlorethylene is recommended.

4. For joining tubing up to 0.030 in. wall thickness the electrode size should not exceed 0.040 in. This assures a favorable electrode current density which is required for thin-section welding.

5. The use of zirconium-oxide-coated or thoriated-tungsten electrodes resulted in a more stable arc. Arc wander is minimized due to the increased emissivity of the electrode.

6. Sounder weld deposits in nickel are obtained through the use of an 80–20% argon-hydrogen mixture, by volume.

7. Argon was preferred to helium when welding light sections of Type 347 stainless steel because the arc voltage was lower and, consequently, for a given value of welding current, less heat energy was developed by the arc.

8. For materials other than nickel, the use of the special shielding eliminated air eddies around the arc and in this manner it was possible to make sound welds consistently on very thin sections.

9. A radio-frequency pilot-spark starting unit was preferred to the use of either a carbon pencil or touching the electrode to the work. Burn-throughs were minimized with spark starting.

10. The inert-arc welding machines described in this paper were excellent tools for research and production. Current values ranging from $^1/_2$ to 150 amp. and spindle speeds from $^1/_4$ to 2500 rpm. allowed investigation of inert-arc welding over a wide range of current and travel speeds on cylindrical parts of various diameters

R. S. Zeno and **H. L. C. Leslie** are connected with the General Electric Co., Knolls Atomic Power Laboratory.

INTRODUCTION

AN INVESTIGATION was made to determine the factors influencing the inert-arc welding of thin-section tubing. The investigation was extended to include the joining of thin to thick, thin to thin, and thick to thick sections by inert-arc welding.

The general plan was to vary conditions such as arc current, joint design, type of electrode, type of gas, gas flow, and travel speed in order to develop a reproducible inert-arc welding method.

MATERIALS

(*a*) A nickel.
(*b*) L nickel.
(*c*) Type 347 stainless steel.
(*d*) S.A.E. 1020 steel.
(*e*) Ductile titanium.
(*f*) Molybdenum.
(*g*) Fernico.

Routine check analyses were made to assure that material mix-ups had not occurred.

SPECIMENS

The first consideration for welding specimens was a joint design which was easy to fabricate and looked reasonably weldable. After several joints were investigated, a few basic designs were formulated as shown in Fig. 1.

INERT-ARC WELDING EQUIPMENT

The welding investigation was carried out on an inert-arc welding machine which was built around a

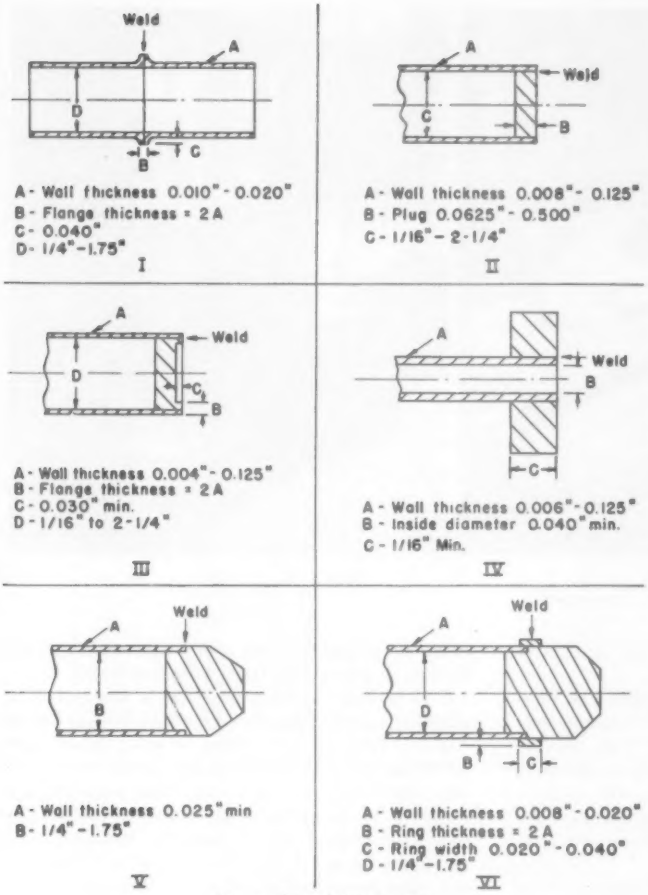

Fig. 1 Basic joint designs

Hardinge lathe Model No. DSM59. The lathe bed was used as the chassis with the compound rest and tool post providing three-directional movement and torch holding, respectively.

A General Electric Type 5 SMY generator and a General Electric Type DO 46X indicator were added for indicating spindle speeds. Knee switches were installed permitting the operator to start or stop the arc. This feature enabled the operator to have both hands available for adjusting the current and/or the arc position during a welding operation (Fig. 2).

The power source feeding the welding machine was delivered through a power and control cubicle, hereafter to be referred to as the power and control unit (Fig. 3). This power and control unit consisted of a series resistor for extra-low-current control, a radio-frequency pilot-spark starting unit, a welding-line contactor, a Thy-Mo-Trol panel for speed control of the welding-machine driving motor and a 150-amp. d.-c. welder.

The welding circuit is outlined in Fig. 4.

Inert gas was delivered to the nozzle through a mixing panel. The panel was designed so that any combination of argon, helium or hydrogen was available (Fig. 2).

Just prior to the conclusion of this investigation we received the newest inert-arc welding machine which had been designed by the Tool and Die Design Section, Apparatus Dept., General Electric Co. The machine was fabricated by the Knolls Atomic Power Laboratory Machine Shop.

Figure 5 shows the new machine which is a more versatile version of the experimental machine shown in Figs. 2 and 3. Special gas shields for containing an inert atmosphere for the experimental machine and the new machine are shown in Figs. 6 and 7, respectively. The special gas shield in Fig. 6 was designed for vertical welding with the work axis horizontal. In essence this consisted of a fused quartz vessel mounted on an electrode holder and closed by a plate mounted on a metal bellows, which made a sliding seal on the headstock chuck face. This arrangement provided excellent visibility and completely excluded air, not only from the arc zone, but from the heat-affected parts of the work as well. The result was clean, bright work with virtually no oxidation colors.

INERT-ARC WELDING PROCEDURES

As the problem consisted of welding tubing that ranged in wall thickness from 0.004 to 0.032 in. and from 0.060 to 2.25-in. O.D., it was necessary to investigate the principal factors influencing the soundness of weld deposits. The main requisite for soundness was a leaktight joint as determined by a mass spectrometer-type leak detector. A preliminary investigation indicated that the variables which should be investigated were as follows: type of current, type of gas, gas flow, type of electrode, arc length, arc current, arc voltage, air eddy currents, travel speed, cleanliness of joint, joint fit, joint design, cleanliness of electrode and method of starting arc.

It was obvious that it would be difficult to hold all the other parameters constant while one was being varied. Therefore a group of welding variables was arbitrarily standardized and others, such as joint preparation, electrode size, type of electrode, electrode

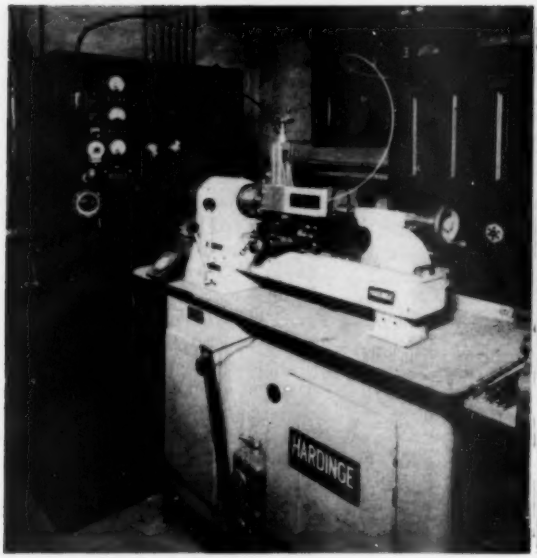

Fig. 2 Inert-arc welding machine, gas mixing panel, and power and control unit used for the welding investigation

Fig. 3 Power and unit control

coating, type of gas, gas flow, arc current, and travel speed were investigated.

After a short time of experimental welding on thin-walled (0.007- to 0.010-in.) Type 347 stainless-steel tubing, it was found necessary to control arc wander, as a fringe impinging upon the tubing would burn through like tissue paper. The greatest trouble-makers in this case were stray air currents around the arc due to fans, opening and closing doors and open windows.

It was found feasible to design shielding for both horizontal and vertical welding to eliminate these air eddies and also to present a means for obtaining a much better type of atmosphere around the joint than was heretofore obtainable.

Many types of materials were investigated for the making of transparent shielding, such as pyrex and flame glass. However, it was found that the one material that consistently did not fail under the conditions of cyclic heating and cooling was fused quartz. In a one and one-half year period not one shield made of fused quartz was broken. Figures 6 and 7 illustrate the type of shielding used for vertical and horizontal welding, respectively.

RESULTS AND DISCUSSION

The first material investigated was Type A nickel. A great deal of difficulty was experienced in producing sound, porosity-free welds. Hundreds of welds were made under various conditions of current, gas flow, and work-travel speed without obtaining sound welds. The resulting welds looked good from an external appearance standpoint and were mechanically satisfactory; however, 95% failed when leak tested.

The porosity problem was finally eliminated by adopting a method developed by R. A. Noland* of the Argonne National Laboratory of using mixed gases for the inert-arc welding of nickel. Mixtures of 80% argon–20% hydrogen by volume were suggested, and proved to be the optimum for consistent results. The technique adopted was to open the hydrogen valve and ignite the gas at the end of the torch. The argon was then introduced allowing the hydrogen to burn around the outer fringes of the argon. The gas mixture was then ready for the welding operation. In all cases some surface porosity was observed. However, every weld which was examined metallographically after using the mixed gases showed that subsurface porosity had been eliminated. Figure 8 illustrates the porous structure of a nickel weld using 100% argon and the cleansing action of the 80% argon–20% hydrogen mixtures.

It was found also that a helium atmosphere was an improvement over the argon atmosphere in the elimination of porosity; however, only the argon-hydrogen mixtures resulted in porosity-free welds.

For the A nickel and all subsequent welding it was found convenient to standardize on the following in order to eliminate some of the variables:

(*a*) 0.030 in. arc length.
(*b*) 0.040-in.-diameter tungsten electrode.
(*c*) Joint designs shown in Fig. 1 (with the exceptions as noted).

* Private correspondence.

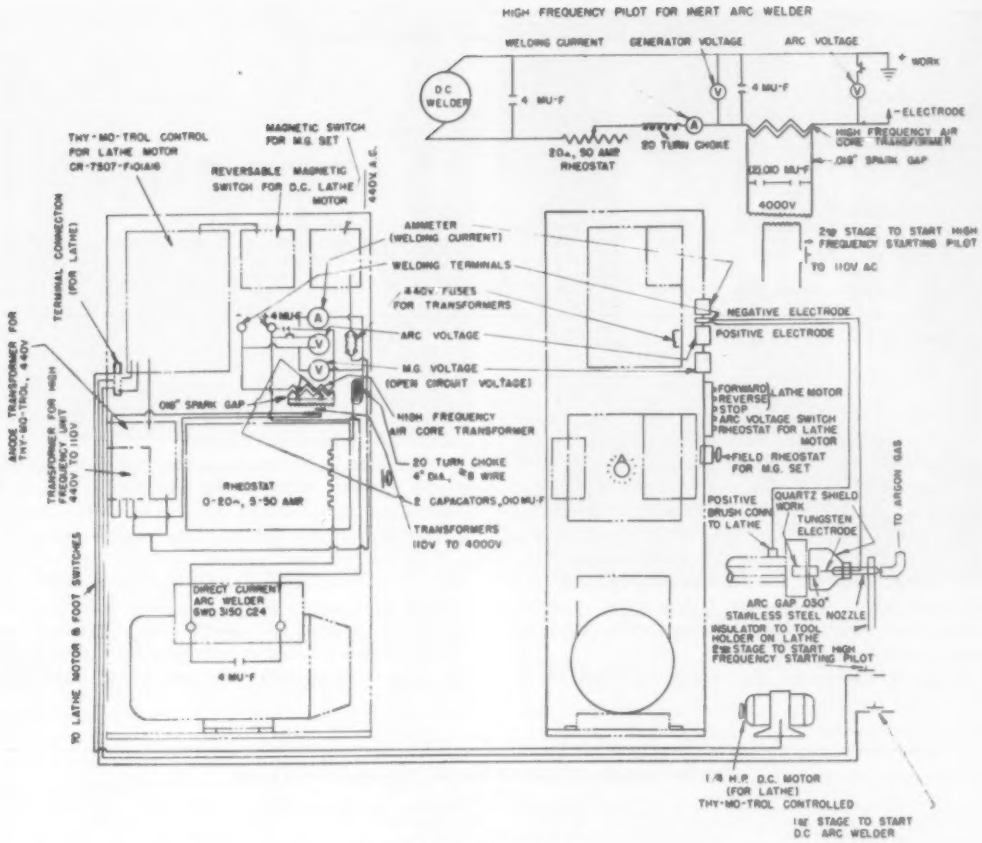

Fig. 4 Welding circuit

(*d*) Direct-current power source.
(*e*) The use of the welding machine shown in Fig. 2.
(*f*) The use of the same operator throughout the investigation.

It was found that the welding characteristics of both Type A and L nickel were similar. Type L nickel (0.01 carbon max.) weld deposits were somewhat cleaner than the Type A nickel (0.1 carbon max.) weld deposits.

Table 1 summarizes the optimum conditions found to be necessary for the inert-arc welding of the various type of nickel joints investigated. These result in a proper heat balance to assure sound welds which were both as strong as the base metal and leaktight. Whenever possible the use of the special gas shield was highly desirable. It could not be used, however, for the nickel welds which required mixed gases and the ignition of the hydrogen. For thin-wall tubing 0.010 in. and under, this shielding eliminated air eddies and room drafts around the joint. It is felt that this shielding was a prime factor in the ability to make

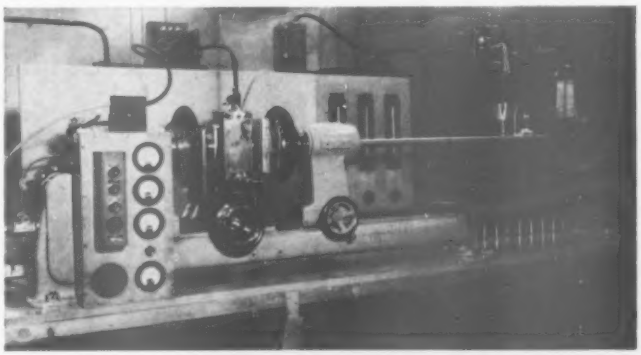

Fig. 5 Newest inert-arc welding machine

Table 1—Inert-Arc Welding of Nickel Tubing

	*Joint design**	*Arc current, d.-c. amp.*	*Linear speed of work, in./min.*	*Type gas and flow, cu. ft./hr.*	*Comments*
I	Wall thickness 0.010–0.020 in.	10–12	5	80% argon–20% hydrogen, by volume; 15	.....
II	Wall thickness 0.010 in.	35	8	Same	Arc was struck in center section of plug for preheat. As soon as puddle formed arc was traversed to joint
III	Wall thickness 0.010 in.	10	5	Same	.....
IV	Wall thickness 0.005–0.030 in.	10–25	7	Same	Same as II above
V	Wall thickness 0.025 in.	25	5	Same	Arc was struck on plug $^1/_8$ in. from joint. As soon as puddle formed arc was traversed to joint
VI	Wall thickness 0.008–0.020 in.	10–25	5	Same	Same as V above

* See Fig. 1.

mechanically sound- and leaktight welds consistently.

In welding Type 347 stainless steel, argon, helium and hydrogen were also investigated singly and in combination. Hydrogen in combination with argon and/or helium did not function in the same manner as with the nickel welds; both of these combinations resulted in a porous weld deposit. Argon and helium combinations and helium alone did not produce as sound weld deposits as 100% argon. Also it was much easier to strike an arc with the high-frequency starting pilot in an argon atmosphere than in helium.

Table 2 summarizes the conditions found to be necessary for the inert arc welding of the Type 347 stainless-steel joints investigated.

Other materials investigated were S.A.E. 1020 steel, ductile titanium, molybdenum and fernico. Table 3 summarizes the optimum conditions found to be necessary for the inert-arc welding of the joints investigated.

With the inert-arc welding machines it was convenient to investigate a multitude of materials in various joint designs due to the ease of varying arc current, arc position and speed of work during welding. It was feasible to start at extremely low currents and speeds and increase each proportionately until puddling

Table 2—Inert-Arc Welding of Type 347 Stainless-Steel Tubing

	*Joint design**	*Arc current, d.-c. amp.*	*Linear speed of work, in./min.*	*Type gas and flow, cu. ft./hr.*	*Comments*
I	Wall thickness 0.010 in.	7	10	Argon 15	Special shield was used (Figs. 6 and 7)
II	Wall thickness 0.006 in.	13	10	Argon 15	Arc was struck in center section of plug for preheat. As soon as puddle formed arc was traversed to joint
III	Wall thickness 0.004–0.010 in.	2–15	6	Argon 15	.....
IV	Wall thickness 0.005–0.125 in.	8–40	10	Argon 15	Same as II above
V	Wall thickness 0.025 in.	30	10	Argon 15	Arc was struck on plug $^1/_8$ in. from joint. As soon as puddle formed arc was traversed to joint
VI	Wall thickness 0.008–0.020 in.	10–20	7	Argon 15	Same as V above

* See Fig. 1.

Table 3—Inert-Arc Welding of S.A.E. 1020 Steel, Ductile Titanium, Molybdenum and Fernico Tubing

Material	*Joint design**	*Arc current, d.-c. amp.*	*Linear speed of work, in./min.*	*Type gas and flow, cu. ft./hr.*	*Comments*
S.A.E. 1020	III—Wall thickness 0.015 in., outside diameter 1 in.	10	9	Argon 15	...
Ductile titanium	III—Wall thickness 0.030 in., outside diameter $1^1/_2$ in.	24	4	Argon 15	Argon backing
Molybdenum	III—Wall thickness 0.005–0.010 in., outside diameter $^1/_{16}$–$^1/_8$ in.	2–4	6	Argon 15	...
Fernico	II, IV and V—Wall thickness 0.030 in.; outside diameter IV, $^3/_{16}$ in., II, V 1 in.	10–20	5	Argon 15	...
Fernico to nickel	IV—Wall thickness 0.030 in., outside diameter $^3/_{16}$ in.	12	5	Argon 15	Plug made of fernico
Fernico to stainless	IV—Wall thickness 0.030 in., outside diameter $^3/_{16}$ in.	14	5	Argon 15	Plug made of fernico

* See Fig. 1.

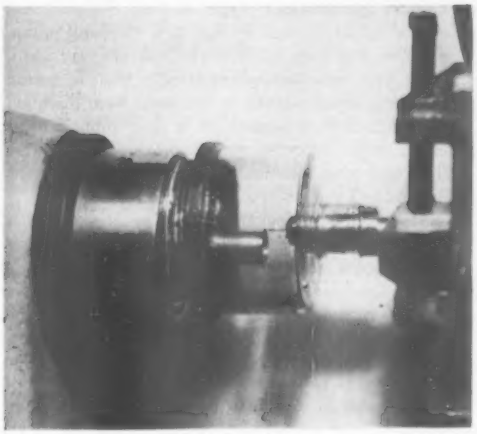

Fig. 6 Special gas shielding for vertical welding with the work axis horizontal

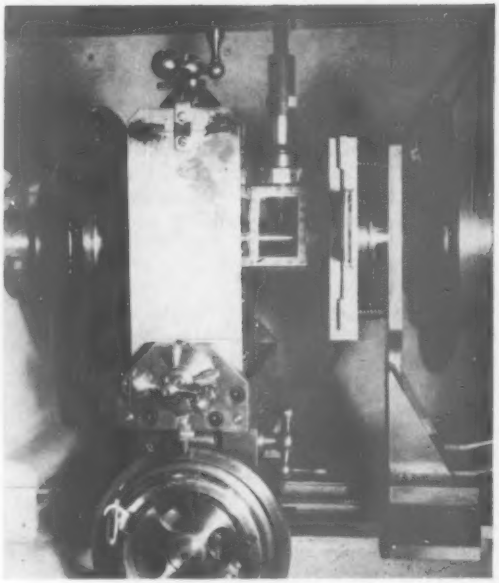

Fig. 7 Special gas shielding for horizontal welding with the work axis vertical

occurred. After a few welds the operator was able to bracket the proper current-speed ratio for any particular material and joint design.

The following general observations were made which applied to all the materials and joint designs investigated:

1. The use of zirconium-oxide-coated electrodes and thoriated-tungsten electrodes improved the welding procedures. The former consisted of dipping the tungsten electrode in a zirconium oxide paste, made by adding a small amount of water to zirconium oxide powder. The composition by volume of the thoriated tungsten was 15% thoria–85% tungsten.

It was found that the coated electrodes or thoriated-tungsten electrodes minimized arc wander and resulted in easier starting of the arc with the use of a high-frequency starting pilot. The zirconium oxide and thorium, respectively, appear to increase the emissivity of the tungsten electrode. Arc wander was also

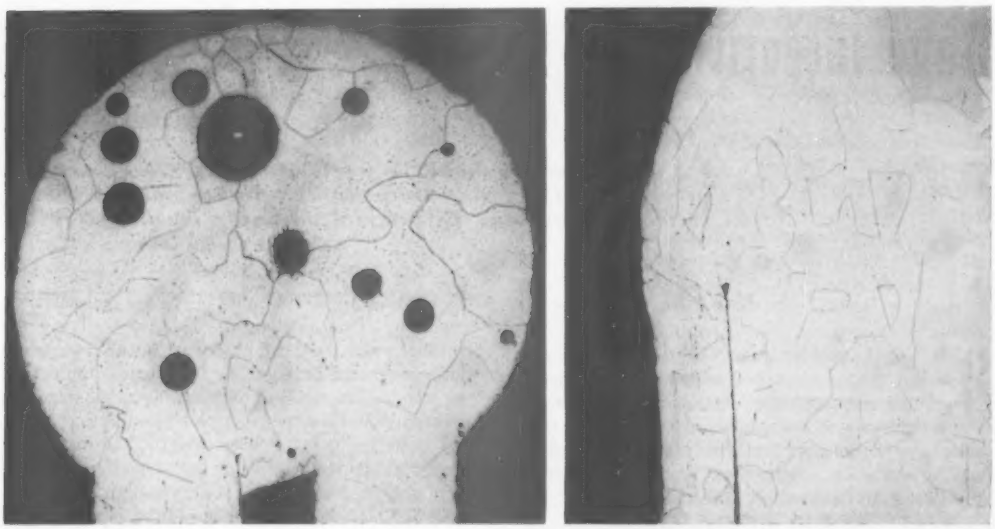

Fig. 8 Nickel inert-arc welds. (Left) Typical porous weld deposit in A nickel welded in 100% argon. 50 ×; (right) sound weld deposit in A nickel welded in a combination of 80% argon and 20% hydrogen by volume. 50 ×

minimized by keeping the electrode free of dust and other foreign matter.

2. The cleanliness of the joint before welding was a major factor. Various methods of preparation were investigated including hydrogen firing, electrolytic cleaning, chemical dips and liquid honing. Finally, it was found that consistent welding results were obtainable without special cleaning precautions, provided only that the material was thoroughly degreased. As a standard practice all materials to be welded were placed in the vapor phase of a trichlorethylene ($Cl\text{-}CH{:}CCl_2$) degreaser for approximately 30 min. before they were removed for welding.

3. The so-called "joint fit-up" was most important, especially where thin sections are involved. A press fit will eliminate the major share of the welding problems. During the course of making 500 welds of joint Type III it was possible to predict in advance on the basis of joint fit-up alone 99% of those welds which would be leaktight.

4. The proper heat balance in the joining of heavy to thin sections (Fig. 1, joint Types II, IV and V) was essential. Invariably the heavy section had to be preheated with the arc until a puddle formed before the arc was directed toward the thinner member. When preheating was eliminated, heat was conducted away from the joint so fast that the thin section would burn away before the heavy section had puddled.

The method used to determine the soundness of all welds was visual inspection followed by leak testing of all welds. This latter procedure, in general, was as follows: Welded samples were inserted in the manifold of a mass spectrometer Type M leak detector and evacuated to 50 microns by use of a roughing pump. The system was then cut into the leak detector itself, and the weld searched systematically with a helium probe. Any leaks existing in the weld were disclosed by the deflection indicated on a d.-c. milliammeter mounted on the leak-detector instrument panel. This method of testing disclosed leaks as small as 10^{-8} c.c. per second or a leak of 3 c.c. in a 10-yr. period.

Joints which were leaktight were then tested under internal pressure on a standard pressure testing machine; in some cases to failure. Through the use of standard formulas it was possible to determine the yield and/or tensile strength of the welds in comparison to the base materials. Other leaktight welds were sectioned and examined metallographically. After some fifty weld joints had been examined by the above procedures, it was decided that a leaktight joint also had good mechanical properties. Subsequently, all welds made were leak tested as the routine method of evaluation.

ACKNOWLEDGMENT

The writers wish to express their appreciation to the following men for their generous assistance in the development, design, and fabrication of the equipment; and in the writing of this paper: A. K. Lehman—Tool and Die Design, Schenectady Works; J. D. Cobine—Research Laboratory; R. W. Clark, E. F. Potter—Schenectady Works Laboratory; O. Bredel, H. G. Winckler, J. P. Jones, E. J. Wade, J. R. Low, Jr., and R. F. Wyer—Knolls Atomic Power Laboratory.

Wage Incentives

A wage incentive should be provided which will keep wages in proportion to increased productivity. Individual skill should receive recognition. By-product advantages will also result

by J. N. McClain

DURING the past six years almost every time you picked up a newspaper you noticed where some group was asking higher wages or higher prices and so on, back and forth, until we have seen the very disastrous inflationary spiral with which you are all so familiar and are wondering—can anything be done to stop it? A lot of remedies have been suggested, but there is one which I do not believe has had sufficient attention. The thing which causes trouble is not the fact that wages are constantly rising, but that wages are rising faster than productivity. As long as the output per man-hour increases at the same rate as the wage rate per man-hour, then the labor cost per unit is constant and there is no inflationary trend. The increase in these two figures was about the same for the first forty years of this century. In the past six years, however, the increase in wages has far surpassed the increase in productivity. The problem then is to increase the productivity, and it is here that the remedy referred

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to above will apply. This remedy is wage incentives. Properly developed and applied, wage incentives will definitely increase the productivity by a substantial amount and thus help to correct the condition pointed out above.

Wage incentives are not new, having been used very successfully in various forms since the days of Taylor at Midvale Steel Co. in the last century. They suffered somewhat from poor application and administration from about 1915 to 1940, but during and since the last war they have been used to great advantage to provide higher wages for the employee and lower unit cost for the employer and consumer.

WHAT TO EXPECT

With a properly developed and administered wage-incentive plan, the output per man-hour will increase by 50 to 100% over what it was before the installation of the incentive plan. It has been proved that the output of the individuals in any group of employees on incentive will distribute itself in a pattern which follows the normal distribution curve about the mid-point. The mid-point is generally found at about 130% of standard, or 30% bonus level. This distribution is shown in Fig. 1. You will note that a few employees (about 2%) do not make any bonus while some (about 2%) make over a 60% bonus.

This is the distribution of the incentive workers, but how about the dayworkers? The average dayworker is found at 70 to 75% of standard so that the increase in output is from 70% of standard to 130%, or almost double. I am considering here an operation which is not controlled by some machine limitation which would prevent such an increase in productivity.

The question then arises: where does this increase in output come from? Does the incentive employee work twice as hard as the daywork employee? The answer is no. This increase in output comes from several sources. First is increased effort on the part of the employee. He is receiving extra money, so he is willing to put forth extra effort. Contrary to what some people will tell you, this usually accounts for less than half the increase in productivity. Second is the decrease in what I call the errors of management—waiting for materials, waiting because of machine breakdown, extra operations, etc. If the employee is being paid daywork he would just as soon wait for materials as work. After all, it is not his fault they were not ordered soon enough—so just kill a half hour until they get here. Third and by no means least is the improvement in methods, resulting in shorter time required, less effort and better safety of operation. I know your operations have all been studied by your foremen, supervisors and management, but you have a man with a watch *write* down everything the operator does, and the time it takes to do each step, and he will usually notice several things which would have been overlooked by merely watching the operation. The man doesn't have to be an expert Methods Man either to notice extra motions and work which the operator is using, and the fact that he uses one hand almost all the time, but uses the other only part of the time. Any wage incentive which is properly developed is based on actual time studies and standard data; therefore, this analysis will be made on each operation. Thus, you can see that this increase in output is not entirely due to extra effort on the part of the employee, but rather to better methods and better control and flow of production.

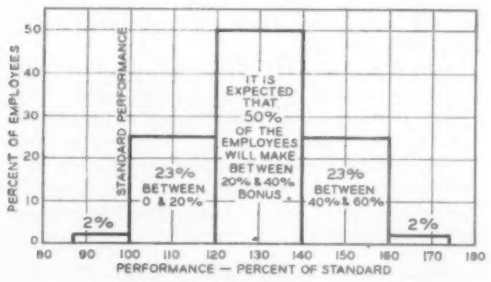

Figure 1

INDIVIDUAL RECOGNITION

We all know that no two people in the world are exactly alike, either in looks, size, shape, habits, likes, dislikes or any other characteristic. Tests have shown that like all the other characteristics of man, the speed and skill with which he works varies among individuals and it follows the usual normal distribution curve such as shown in Fig. 1. These tests show that the fastest operator runs about twice the production the slowest operator will run. This is based on qualified operators too, not including learners. If some employees are going to produce twice as much as other employees, then why should they be paid the same wages? We have always had what we call a "Range of Rates" on each job. For example, a job paid $1.25 to $1.40 per hour. Periodically, as a man's skill improved we would give him another nickel an hour until he reached the $1.40 rate. However, these ranges allow only about 10 to 20% difference between the man with the least skill and the man with the highest skill. The tests mentioned above showed there is 100% difference. During the past few years pressure has been exerted by the labor unions, and in a large number of instances successfully, to do away with this range of rates and pay everyone on a certain job the same rate of pay. I say this is wrong. Let's recognize the individual and quit making machines out of our employees and only recognizing them by a number. If one employee has the extra skill and is willing to put forth the extra effort to produce twice as much as the slowest employee and 35% more than the average, then his extra skill and effort should be recognized and he should be rewarded in proportion.

REQUIREMENTS OF GOOD WAGE-INCENTIVE PLAN

No single wage-incentive plan can be called the per-

fect plan or the best plan for all plants. Each plant has its own differences which require modification of any basic plan to fit the requirements of that plant. There are, however, certain basic requirements of any successful incentive plan. These are as follows:

1. Simplicity. If the plan is to be truly successful it must be readily understood by the employees and they should be able to compute their earnings and know how the productions standards are set.

2. Base Rates Set by Job Evaluation. If the plan does not provide equitable pay for all jobs, then there will be ill feeling among the employees and the result will be low morale. The expected increase in productivity will never be gained with low morale. In order to provide equitable pay for all jobs the base on which the pay is computed must be equitable and fair. The best way I know of making base hourly rates equitable is by job evaluation.

3. Production Standards Based on Time Study and Standard Data. Just as the base rates must be equitable, so must be the production standards. The standards must be such that for a given level of effort and skill the same percentage of bonus will be earned on all jobs. The only way to attain this is by detailed time studies and/or standard data. These production standards if properly established, based on accurate data, should not be put on a negotiable basis. If they are, inequities will result and you will no longer have a wage structure which is equitable to all employees. They should be subject to restudy and discussion, however, but stick by the facts.

4. Individual if Possible. Group plans are the lazy man's way of setting standards. Although they cannot be avoided in certain instances where the group all work together and help each other, or in line groups such as assembly lines where the output of one employee in directly controlled by that of the man in front of and behind him, the best results will be obtained when each man is paid according to his own output. One of our objectives in installing the incentive plan is to recognize the skill and effort of the individual; then why have him held back by the lower output of several other members of a group? He is not going to continue his extra output above the average of the group when he receives nothing in return for it. So the incentive should be on an individual basis wherever possible, and where a group is the only practical solution then make the group as small as possible.

5. Provision for Keeping Up to Date. Any incentive plan is only as good as the administration it receives. If the plan is to remain equitable, any change which is made in the operations should be reflected by a change in the incentive. The job evaluation and the production standards must be kept up to date. If you are not going to keep it up to date then you will be better off not to install the plan in the first place.

BY-PRODUCTS OF INCENTIVE PLAN

When an incentive plan is installed there are a lot of side benefits which are found in addition to the two main benefits of higher pay and higher productivity. It should be recognized before installing the incentive plan that your timekeeping costs are going to increase. So write off some of this extra timekeeping costs to these side benefits.

1. Better Methods. I have mentioned above how better methods result from detail time study and job analysis.

2. Lower Costs Through Better Methods. Better methods should result in lower unit costs and better quality.

3. Smaller Number of Employees on Pay Roll. With our present fringe benefits and unemployment insurance, every employee adds other costs in addition to his direct wages. Therefore, if we can produce the same goods with half the employees, we will realize a considerable savings in addition to the savings in direct labor.

4. Cost Control. Although others may disagree, I believe that a good incentive-wage structure should provide a constant unit cost. In this manner the direct labor cost is definitely controlled.

5. Performance Measurement. A lot of systems and devices have been conceived to measure output, but none give the accurate picture given by a good incentive plan. The superintendent will know the performance level of each group daily, and there is a competitive spirit built up among the various groups. Everyone wants to head the list. Also, it tells each man how he compares with the other men in his department.

6. Accurate Scheduling. Production standards provide accurate data for scheduling purposes. All you need is the production standards and the average performance of each group.

7. Plant Layout. Production standards provide information which is very useful in studying flow of materials and plant layout.

8. Points Out Poor Management. Do not make the mistake of thinking that once the incentive system is installed the supervisor and foreman can then sit in an easy chair and watch the production flow. The incentive will make the job easier in that the men will work harder, but they also will expect and demand that they not be held up by materials or other reasons. It, therefore, will require more planning and scheduling on the part of the supervision.

I have attempted in the above to give you a brief and factual look at wage incentives. I do not believe they are the answer to all our wage troubles at the present time, but they certainly will help. They require a lot of work, good psychology, good personnel relations and understanding by all concerned. In the end, however, I have no doubt that they will repay severalfold in many ways for all the effort.

Pressure Welding

Part III—Hot-Pressure Welding

Historical review of hot-pressure welding, classification of welding processes, precautions, procedures, design, quality control and special applications to aluminum and its alloys

by Frank S. Gardner

INTRODUCTION

EARLY examples of the hot-pressure welding process are found in the production of laminated steel swords by swordsmiths and the fabrication of silver and gold articles of jewelry by the silversmiths. The latter artisans also were responsible for the development of the well-known "Sheffield plate," copper sheet clad with silver, originally with a solder bond but now more commonly by a hot-pressure welding process. Today, the production of clad metals is an industry by itself.

At present, too, a great many tons of 24-in. diameter pipe sections for overland pipe lines, as well as heavy steel railroad track, are being joined by a modern adaptation of the blacksmith's art. Further, the advent of powder metallurgy, which consists of pressing and sintering metal powders into solid shapes, has resulted in the development of another industry entirely dependent upon the ability of metals to be hot-pressure welded.

Among metallurgists and welding engineers, hot-pressure welding has taken a place beside the better-known, conventional joining methods. The process is differentiated sharply from flash, resistance and fusion welding, as well as from the brazing and solder techniques, by two characteristics. First, there is no melting of the metals to be joined. Second, no third material is introduced into the joint.

A broad survey of hot-pressure welding[1–9,*] reveals a few of the more common process variations. The type of joint, or the shapes being joined, afford a convenient means of classification for summary purposes. See Table 1.

Table 1—Classification of Hot-Pressure Welding Processes

Shapes being welded	*Type of joint*	*Basic equipment needed*	*Some methods of heating joint*
Sheet and strip	Lap (spot and line)	Dies and press	Calrod-heated dies, flame-heated dies
Barstock and tubing	Butt	Press	Induction coil, oxy-acetylene burner
Laminated or clad metals	Overlay, cladding	Rolls or press	Furnace preheating of parts

Adaptation of the three basic processes listed in Table 1 to the joining of simple or preformed parts makes possible the fabrication of a great variety of shapes. Experience has indicated no basic welding restriction, except perhaps upon extreme material thickness. Moreover, theoretically there is no limit to the similar and dissimilar metal joints that can be made. Table 2 shows some of the practical dissimilar-metal combinations.

Thus, the field of application for hot-pressure welding is large but is limited, as are all processes, to those cases where, in competition with other methods, it is more economical or the physical properties of the joint are superior.

THEORY AND PRACTICE

Pressure welding of metals, either at room temperature or above, may be defined as bonding brought about by special mutual deformation of two materials at a temperature below the melting range of either. Speculations on the nature of the bond suggest that it results from forced interlocking of the atoms; interlocking by diffusion probably occurs simultaneously, and of course this is greater at elevated temperatures. Some synonyms for hot-pressure welding reflect its origin: these are "solid-phase welding," "recrystallization welding" and "forge welding."

Some preparation of the surfaces to be joined is usually employed to promote intimacy of contact. The use of a 6 in. diameter wire brush rotating at 3450 rpm. has been found very satisfactory for aluminum

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* A selected bibliography follows the text. The subject report is drawn both from original work and that of others in the bibliography. It would detract from the presentation to attempt to assign the source of every statement, so this has been done only as convenient.

Table 2—Laminated Metals

Some combinations produced by dry bonding (hot-pressure welding), moist bonding and wet bonding—products of General Plate Division. Other combinations on request.

	Platinum	Palladium	Gold	Silver	Aluminum	Brass	Copper	Beryllium copper	Iron	Invar	Stainless steel	Phos. bronze	Monel	Nickel	Silver solder	Steel (SAE 1010)	Nickel silver
Platinum	..	..	SWT*	SWT	..	SWT	SWT	..	SW	SW	..	SWT	SWT	SWT	SW	SW	SWT
Palladium	..	..	SWT	SWT	..	SWT	SWT	..	SW	SW	..	SWT	SWT	SWT	SW	SW	SWT
Gold	SWT	SWT	..	SWT	SWT	SWT	SWT	S	SWT	SW	SW	SWT	SWT	SWT	SWT	SWT	SWT
Silver	SWT	SWT	SWT	..	SWT	SWT	SWT	S	SWT	SW	..	SWT	SW	SW	SWT	SWT	SWT
Aluminum	..	..	SWT	SWT	..	S	SWT	..	..	..	..	..	..	..	..	..	..
Brass	SWT	SWT	SWT	SWT	S	..	..	..	SW	SW	S	SW	SW	SWT	SWT	SWT	..
Copper	SW	SWT	SWT	SWT	SWT	..	..	..	SWT	SW	..	S	SW	SWT	SWT	SWT	SWT
Beryllium copper	..	..	S	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Iron	SW	SW	SWT	SWT	..	SW	SWT	..	..	S	S	S	SW	SW	S	..	SW
Invar	SW	SW	SW	SW	..	SW	SW	..	S	..	S	SW	S	S	..	S	SW
Stainless steel	..	..	SW	..	..	S	..	..	S	S	..	..	S	S	..	..	S
Phos. bronze	SWT	SWT	SWT	SWT	..	SW	S	..	S	SW	..	..	SW	SWT	SWT	SW	SWT
Monel	SWT	SWT	SWT	SW	..	SW	SW	..	SW	S	S	SW	..	..	..	SW	SW
Nickel	SWT	SWT	SWT	SW	..	SWT	SWT	..	SW	S	S	SWT	..	..	..	SW	SW
Silver solder	SW	SW	SWT	SWT	..	SWT	SWT	..	S	..	..	SWT	S	S	..	S	SWT
Steel (SAE 1010)	SW	SW	SWT	SWT	..	SWT	SWT	..	..	S	..	SW	SW	SW	S	..	SW
Nickel silver	SWT	SWT	SWT	SWT	..	..	SWT	..	SW	SW	S	SWT	SW	SW	SWT	SW	..

* S = sheet, W = wire and T = tubing.

sheet. As an alternative, sand or grit blasting may be employed. These operations remove foreign matter, oxides and adsorbed films. They also produce minute hills and valleys, but it is not certain what basic significance is attached to the relative smoothness of the surfaces being joined. Extreme smoothness is desirable for flame-heated joints in bar stock, but in this case better exclusion of air is probably being sought.[4]

Without doubt, fresh metal surfaces are quickly "contaminated" when exposed to the atmosphere. In the case of aluminum, much has been written about the rapid loss of weldability after the stock has been wire brushed.[5] It is the writer's opinion, however, that undue emphasis has been placed on this action. Satisfactory hot-welded lap joints in cold-rolled aluminum sheet (Types 2S and 3S) have been obtained frequently using as-received or degreased surfaces. This practice, however, as yet cannot be recommended because weld quality can be unpredictable. Occasionally immunity has not been noticed when making similar cold welds, which invariably require that the stock be wire brushed.

Heating the joint aids in its formation by allowing greater diffusion. Heating may also cause evaporation of the adsorbed films. A third effect is the softening and easier deformation of the metal between the dies; this reduces the press capacity required. Fourth, heating may bring about recrystallization and grain growth across the interface. For aluminum at least, the net effect of heating is the production of an equivalent bond with less deformation. This is in spite of the unavoidable surface oxidation which accompanies heating and would be expected to render welding more difficult.

Deformation of the joint is the most critical operation of the pressure-welding process. It is well recognized that a minimum percentage of thickness reduction is necessary for lap joints and for clad metals, and a minimum amount of "gather" or upset for butt joints. With these deformations lies the success of pressure welding, but they are still crude in that the needed metal deformation is only along and very close to the weld interface, while that in the back-up metal is extraneous. The role of deformation on an atomic scale is not known; on a gross scale, however, some of its simultaneous actions can be identified as follows:

1. Deformation promotes a high degree of approach between the two metal surfaces, by plastic compression.

2. Deformation causes lateral flow or "extrusion" of metal in both sheets by plastic compression. This destroys the continuity of any surface films.

It is a practical observation that, to some extent, deformation is interchangeable with temperature. Thus, undesirable thinning of the metal adjacent to the weld in lap joints can be lessened by welding at a higher temperature.

The press capacity necessary to produce sufficient deformation is approximately that required to cause yielding of the metal under the dies. Therefore, the yield point of the material at the welding temperature, multiplied by the effective die area, give the minimum force that must be exerted by the press.

A time factor enters into the hot-welding cycle because the interface must be heated by conduction, which obviously requires some time. Thus, short welding cycles may produce joints which, to some extent, resemble cold welds. This is illustrated well by lap joints in aluminum. In Fig. 1, the bottom chart shows the interface heating curve for dies at several

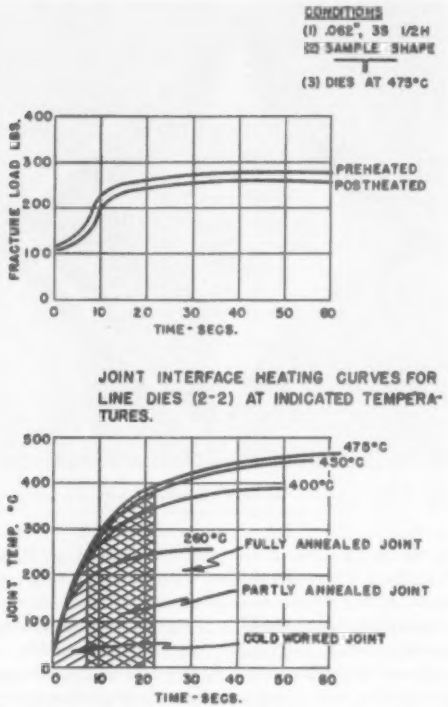

Fig. 1 Effect of preheat time and postheat time on fracture load of lap joints in tensile bend tests

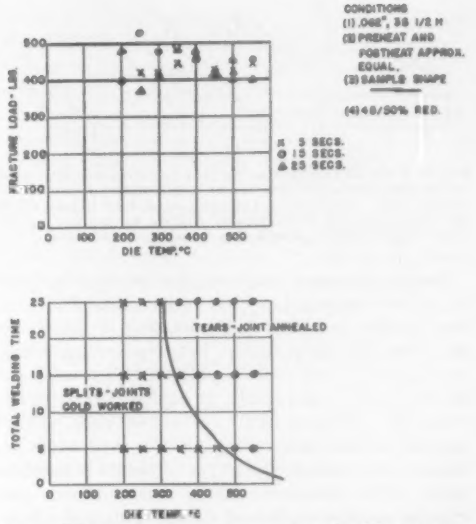

Fig. 2 Effect of die temperature and total welding time on fracture load of lap joints in tensile shear tests

temperatures. The top chart reveals the fracture load for samples tested in tension under arbitrary bending conditions. Some samples were intentionally preheated prior to deformation; others were heated after deformation.

The indications are that the metal in contact with the dies must be heated for about 15 sec., either before or after deformation, to produce a hot-welded joint which is ductile because it has been completely annealed. In this type of test, a shorter contact time is revealed by a lower fracture load. The satisfactory fracture loads of postheated samples are very significant. Since they were deformed within one or two seconds, they are essentially cold welds that have been annealed. Process modifications are obvious.

In Fig. 2, the effect of die temperature and total welding (contact) time is evaluated for lap joints tested in tension under arbitrary conditions approaching single shear. The bottom chart shows that increasing exposure of the joint to heat is accompanied by a change from a split failure to a tear failure.* The top chart demonstrates that, in this test at least, the fracture load is not sensitive to wide variations in heat exposure during welding. In summary, the most significant role of time in hot-pressure welding is that of implementing heat penetration to anneal the joint and thereby increase its ductility.

While metals and alloys suitable for hot-pressure welding are many, the materials commonly joined are few. In part, this is due to limited knowledge and experience, but other factors must be recognized. Two primary requirements must be met: first, a moderate amount of deformation must be sufficient for satisfactory joining; second, heating to the plastic range in air must not be accompanied by harmful oxidation. Aluminum and some of its alloys are outstanding in these respects, particularly since their plastic range is below red heat. Both plain and alloyed low- and medium-carbon steels, as well as the stainless grades, have met these demands in butt joints and clad metals; so far other welding methods excel for lap joints in sheet and strip. Copper and copper-base alloys have been used in all three types of hot-pressure-welded joints, but only the butt joint is known to be used in industry. Here, as for steels, the necessary deformation is greater than for aluminum, and applications correspondingly are more limited. Metal pairs suitable for dissimilar-metal joints are well appraised by reference to Table 2, which includes hot-pressure-welded laminated metals available from the General Plate Division.

DESIGN AND QUALITY CONTROL OF LAP JOINTS IN ALUMINUM STRIP AND SHEET

The ductility developed in a hot-pressure weld was illustrated previously. Mention also was made of the desirability of failure by tearing rather than by splitting, since the latter may be likened to a brittle failure.

* Lap joints are usefully described by their manner of failure. A split corresponds to cleavage along the interface. A tear indicates failure in the thinned metal adjacent to the weld. The manner of failure is partially dependent upon test conditions, but a tear failure serves as a rough indication of a satisfactory joint, whereas a split casts doubt on the joint properties.

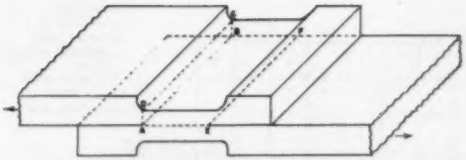

Fig. 3 Possible fracture paths in a hot-pressure line weld made with flat anvil dies, when subjected to single-shear tensile test. Failure by splitting occurs in plane AEFB at low-percentage reductions; failure by tearing across plane ABCD at higher-percentage reductions

The attainment of maximum strength in a lap joint is not so obvious and requires explanation. In Fig. 3, two fracture paths are indicated, and in this single shear test both are possible. In low-percentage reductions, splitting will occur in plane *AEFB* because the interface is the "weak link." In high-percentage reductions, the aluminum will tear across plane *ABCD* because this will be the "weak link." At some intermediate deformation either type of failure is likely to occur. Here, maximum strength is obtained, and repeated samples are divided in their manner of failure. The situation is shown schematically in Fig. 4, where the load-carrying ability of the interface and adjacent metal are plotted against deformation. The net load-carrying ability is described qualitatively by the lower portion of each curve.

For the many service conditions where stress conditions are approximated by the single-shear test, a series of test samples made with increasing deformation will reveal the optimum amount to employ. This is the lowest percentage reduction which consistently yields a tear failure; such a joint will have almost the maximum strength. A great many tests of wire-brushed Types 2S and 3S aluminum hot pressure welded at 500 to 550° C. have shown that maximum strength occurs at about 45% reduction, and the optimum reduction is 50 to 55%. The reduction values are increased as the welding temperature decreases, so that at room temperature the transition from split to tear failures occurs at 65 to 70% reduction and the optimum value is somewhat higher.

In view of the foregoing analysis of lap-weld strength, it is seen that this property is only qualitatively related

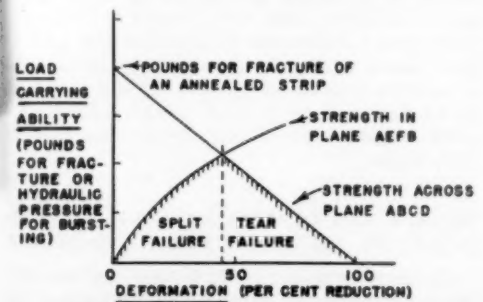

Fig. 4 Schematic plot of load-carrying ability of fully annealed hot-pressure line welds (dies at 500° C.) versus deformation

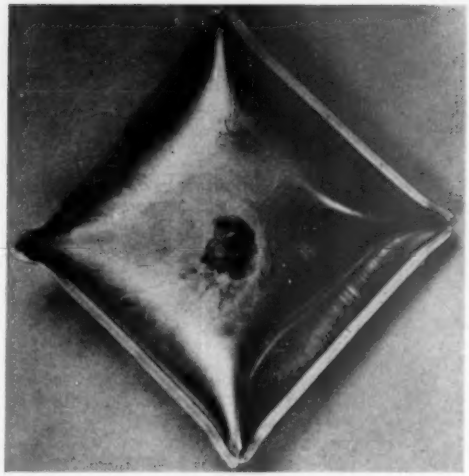

Fig. 5 Hot-pressure-welded aluminum pillow after pressure testing

to the anvil area at low reductions, and at higher reductions where the desired tear failure is obtained, there is no relationship whatever. Thus, strength values must be expressed as a rupture load or bursting pressure for a particular weld. For line welds, an arbitrary design strength might be expressed as strength per unit *length* of a weld made in a particular fashion.

The conventional "pillow test" is very valuable for demonstrating the quality of line-welded joints (see Fig. 5). Weld uniformity is revealed by leak-tightness, and weld ductility is manifested by the extreme distortion prior to bursting. For round pillows, a graph of bursting pressure versus percentage reduction exhibits behavior identical to that indicated for the single-shear tensile test. Either shape of pillow would provide a means of quality control, the choice being dictated by the nature of the equipment.

PRACTICE FOR LAP JOINTS IN ALUMINUM SHEET AND STRIP

Various applications of lap joints in aluminum strip and sheet, as described hereafter, have revealed general information on this type of joint. First of all, considerable latitude is possible in die dimensions to obtain satisfactory welds. Basic die construction is a pair of matching anvils, relieved with tapered or curved sides. For some welds, the anvil approximates a spot; for line welds its length extends indefinitely. A. B. Sowter in England[13] stated that undirectional flow from under the sides of a long or rectangular die is preferable to radial flow from under a circular die. This has been confirmed tentatively. The thinner and harder the sheet, the smaller may be the die width, and vice versa. However, die widths, from one half to twice the sheet thickness are satisfactory for aluminum, with some preference for the latter because the

width of the weld interface is greater. In welding two or more similar sheets, optimum results are obtained with similar top and bottom dies.

There is some evidence in favor of providing a channel around the die anvil into which excess metal may flow conveniently. This channel also lessens the lateral extension which accompanies welding.

Shoulders, much larger in area than the anvils, may be located so as to impinge upon the strip or sheet surface and control penetration or per cent reduction. These same shoulders will hold the sheet down, overcoming its natural tendency to curl up adjacent to the die.

Line-weld dies are subject to thermal bowing, but this can be removed as the weld is being made, by simultaneous engagement of a pair of die shoulders, either directly or through a variable-thickness spacer bar, which also provides easy control over per cent reduction. This remedy may be used for edge welds, but of course would be inapplicable for mid-sheet welds.

To minimize heating of the press, particularly the ram head, water cooling of the die supports may be desirable. Proper placement of $^1/_8$-in. Micalex sheet in the die mounts also is helpful in confining the heat. Silicone grease performs well as a lubricant.

A proved material for hot-welding dies is high-carbon, high-chromium tool steel. Calrod heating elements with Inconel sheaths are highly satisfactory. Elements of 0.33 in. diameter may be flattened to rectangular units of 0.22 in. thickness.

Trouble may be experienced due to the dies sticking to the sheets being welded. This difficulty is promoted by die designs which confine the metal rather than allowing it to escape easily, and is more likely to occur when welding thin stock (for example, 0.020 in.) which tears quite easily when hot. Accumulations of oxide and aluminum fragments, and prolonged contact time, can cause sticking.

However, sticking may be avoided consistently by giving proper attention to the above factors. This alone will be the remedy in many cases; when other changes are ineffective or impossible, an antisticking coating may be used. Magnesia in water is an effective coating and is readily removed by subsequent washing.

Repair welding is possible. Accidentally poor hot-pressure welds, subjected to water-coverage of the interface, have been rewelded successfully by adding 5 to 10% more deformation.

Two or more sheets may be welded simultaneously; three and four sheets of $^1/_{16}$-in. thick aluminum have been welded. The extra sheets may be narrow back-up strips, added for stiffening purposes. Three- and four-sheet welds are shown in Fig. 6. In the same photograph is shown a weld in $^1/_8$-in. stock, the heaviest material welded so far.

APPLICATIONS

Large Aluminum Containers

A wide variety of strong leak-tight containers may be designed around sized and preformed sheet stock, deep drawn parts, extrusions, castings, etc. The square pillow of Fig. 5 represents a basic design, variations of which could be developed for specific applications.

A schematic view of the press used for this work is shown in Fig. 7. A close-up of the die set, Figure 8, shows the rigid construction and the water-cooling jacket adjacent to the ram head. Hardened steel pins, lubricated with silicone grease and working in bronze bushings, provide for easy motion of the top die member with the press capstan wheel. Micalex, $^1/_8$ in. thick, partially insulates the hot dies from their backing.

A pair of line dies are shown in Fig. 9. Each die is 16 in. long with milled slots for partially flattened Calrod heating elements, and is bolted to its backup from the rear through clearance holes which allow for elastic thermal bowing. This bowing is removed

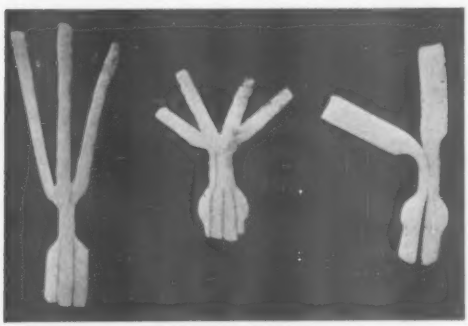

Fig. 6 Assorted hot-pressure-welded lap joints. 3 sheets of $^1/_{16}$-in. 3S-$^1/_2$ H aluminum. 4 sheets of $^1/_{16}$-in. 3S-$^1/_2$ H aluminum. 2 sheets of $^1/_4$-in. 4S-$^1/_2$ H aluminum

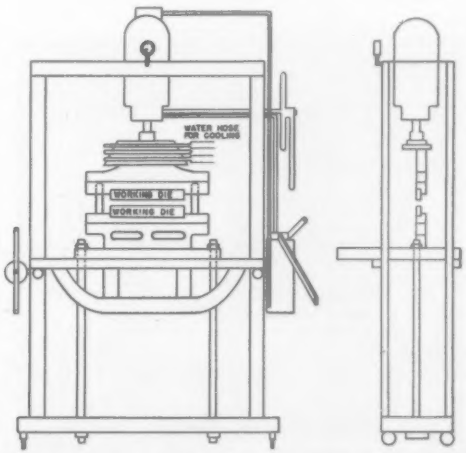

Fig. 7 Schematic drawing of 50-ton press and working dies

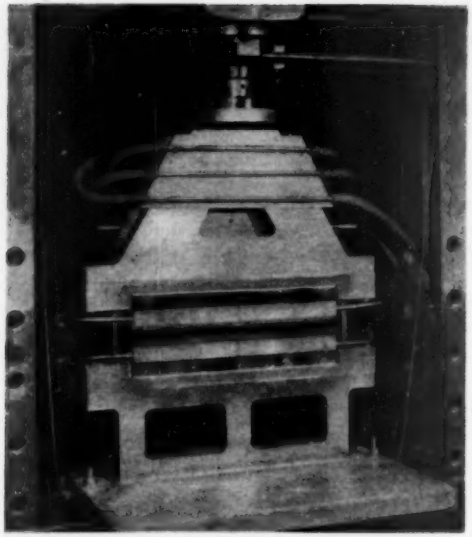

Fig. 8 Experimental die set for hot-pressure line welds up to 16 in. long, with die temperatures up to 550° C. (1022° F.)

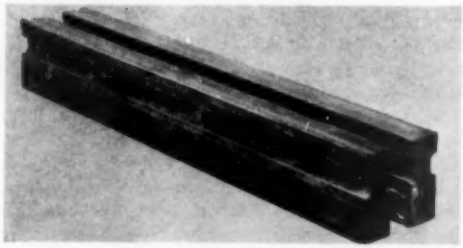

Fig. 9 Calrod-heated dies for hot-pressure line welding of aluminum sheet and strip

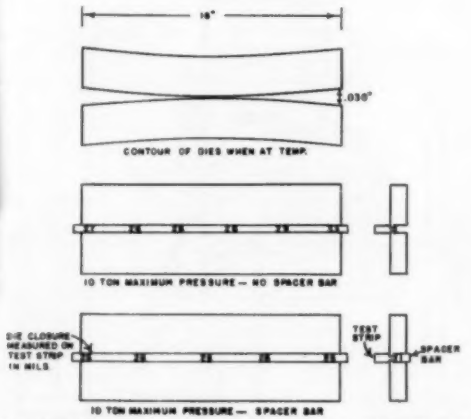
16"
.030"
CONTOUR OF DIES WHEN AT TEMP.
10 TON MAXIMUM PRESSURE — NO SPACER BAR
DIE CLOSURE MEASURED ON TEST STRIP IN MILS
TEST STRIP
SPACER BAR
10 TON MAXIMUM PRESSURE — SPACER BAR

Fig. 10 Use of spacer bar to eliminate thermal bowing of line dies

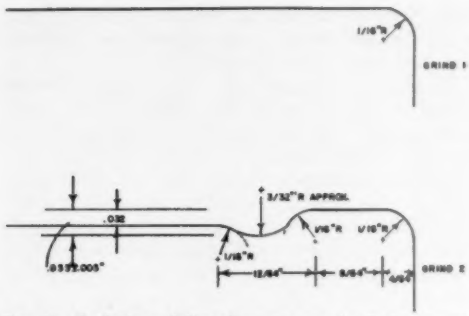

Fig. 11 Evolution of line die contours for hot-pressure welding with die pair No. 2

during welding by placing a spacer bar between the rear shoulders of the dies, as depicted in Fig. 10.

Two useful line-die contours are shown in Fig. 11. Grind 1 provides complete welding of the flange edges. With it, positioning of parts is not critical, but the welded flanges may project considerably as a result of lateral extrusion. Grind 2 employs a smooth, narrow channel between the working face and the shoulder clamp; metal is extruded from under the working face into the channel. Welds made with the latter die set have a pleasing appearance, exhibit less widening of the flange and demonstrate very satisfactory joint properties.

Type 3S-$^1/_2$ H aluminum sheet stock, $^1/_{16}$ in. thick, was employed for the square pillow. Preparation for welding included wire brushing of the mating surfaces and painting the surfaces which contacted the dies with antisticking material. Die temperature was about 500° C. (932° F.). The cycle for each of the four welds was 30 sec. A load of ten tons was held for 10 sec., increased to 19 tons during the next 15 sec., and held at 19 tons for 5 sec. more. The unit was held by hand and the welds made continuously. Joint reduction was constant within 50 to 55%. Containers produced by this method have passed severe tests which indicate they are leak-tight.

INVISIBLE LAP JOINTS IN ALUMINUM STRIP

Special purpose cables are sometimes protected with a spiral winding of aluminum strip similar to the steel sheathing of the familiar BX cable (Fig. 12). The

Fig. 12 Reel of Type 2S-$^1/_2$ H aluminum strip, 0.023 in. thick by 0.75 in. wide, and armored cable wrapping made from it

Fig. 13 Six-ton press and Calrod-heated dies for hot-pressure-welded lap joints in aluminum strip

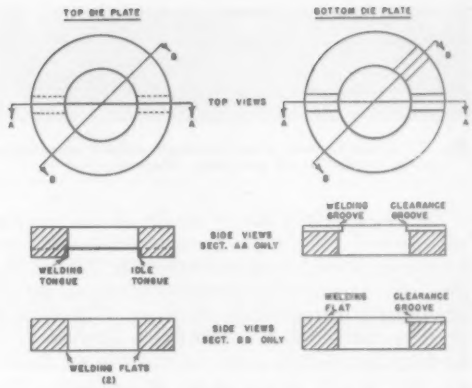
TOP DIE PLATE
BOTTOM DIE PLATE
TOP VIEWS
WELDING GROOVE
CLEARANCE GROOVE
SIDE VIEWS SECT. AA ONLY
WELDING TONGUE
IDLE TONGUE
WELDING FLAT
CLEARANCE GROOVE
SIDE VIEWS SECT. BB ONLY
WELDING FLATS (2)
NOTE: LATERAL MOVEMENT OF METAL IS PREVENTED WITH STRIPS IN "AA" POSITION.
LATERAL MOVEMENT OF METAL IS ALLOWED WITH STRIPS IN "BB" POSITION.

Fig. 15 Experimental die plate pair for hot-pressure-welded lap joints in aluminum strip

strip used to make windings must be joined as the reels are consumed and the joint must be smooth and ductile enough to pass through the forming tools and withstand subsequent service requirements. (The strip employed is 2S-½H aluminum, 0.75 in. wide by 0.023 in. thick.) An almost invisible hot-pressure welded joint has been proposed for this application.

The joint is made by overlapping the ends to be joined 1/8 to 3/16 in. and compressing the lapped portion between flat dies to the thickness of one strip, or 50% reduction. The experimental welding assembly is shown in Fig. 13 and a close-up of the dies in Fig. 14. Reference to the drawings in Fig. 15 explains the two welding positions that were tried. A joint welded in the *AA* position is made in a groove so that lateral movement of the metal is prevented. Welds made in the *BB* position, however, are laid on flats and metal movement in all directions is possible. In the latter case, the flash is trimmed off after welding (Fig. 16).

The greatest difficulty in the production of a joint of this type arises from incomplete welding at the extreme ends of the lap. This produces a "sliver" which will catch and be a point of weakness. It is eliminated by attention to details, especially to the wire brushing of the surfaces to be lapped beyond the apparent overlap.

Joints made in the *AA* groove suffered from damage incurred when they were forcibly removed from the groove. This can be alleviated by dusting the strip with mica or magnesia oxide powder before welding, but wedging of metal between the tongue and groove of the dies still leaves a poorly shaped joint.

Fig. 14 Close-up of completed joint made with flat dies. Joints with side restraint are made in the empty groove

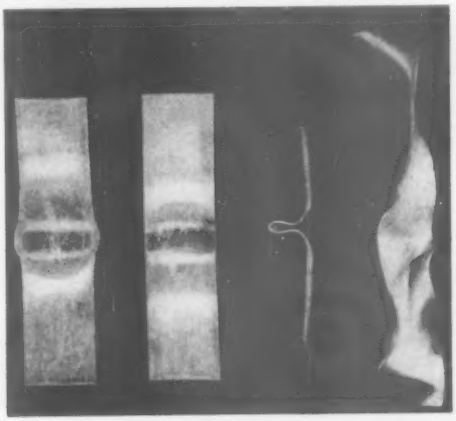

Fig. 16 Hot-pressure-welded lap joints

Fig. 17 Cross section of hot-pressure-welded aluminum strip, welded in BB position. Magnification 9 ×

The simple welding flats of the *BB* position met the requirements well. Sticking was avoided easily by interposing a sheet of mica between the lap and the dies. End imperfections were removed in the trimming process and slivers were no problem. The welding cycle was not critical, but one which consistently gave good results was as follows: load at one ton for 20 sec. and then at three tons for 20 sec. more. Die temperature was maintained at 550° C.

A representative joint exhibits the microstructure shown in Fig. 17. Tensile test results on 22 samples averaged 168 lb. load at failure and 8% elongation. Fracture always occurred at some point on the lapped length. The average tensile strength, spreading the fracture load over the joint (and strip) cross section, is calculated at 9700 psi. The tensile strength of annealed material (Type 2S-O) is about 13,600 psi., indicating a joint efficiency of 72%. On the basis of the results, a similar joint in sheet material can be predicted confidently.

SMALL ALUMINUM CONTAINERS

Hot-pressure welded containers may also find application for small high-production items. One of these is the common "tomato can," made with a soldered tin-plate body, and covers that are attached by a mechanical seaming process.

Both of these operations have been conducted by pressure welding in Fig. 18, which shows 2-in. diameter experimental cans made from 0.020-in. Type 3S-$^1/_2$H aluminum stock. A developed length is formed into a cylinder, line welded, and one end flanged by spinning. A bottom is then ring welded in place, spun flush with the sides of the cylinder and a cover with a pressure fitting is ring welded to the other end. The completed unit has been tested under water and has shown no leaks with about 5 psi. air pressure.

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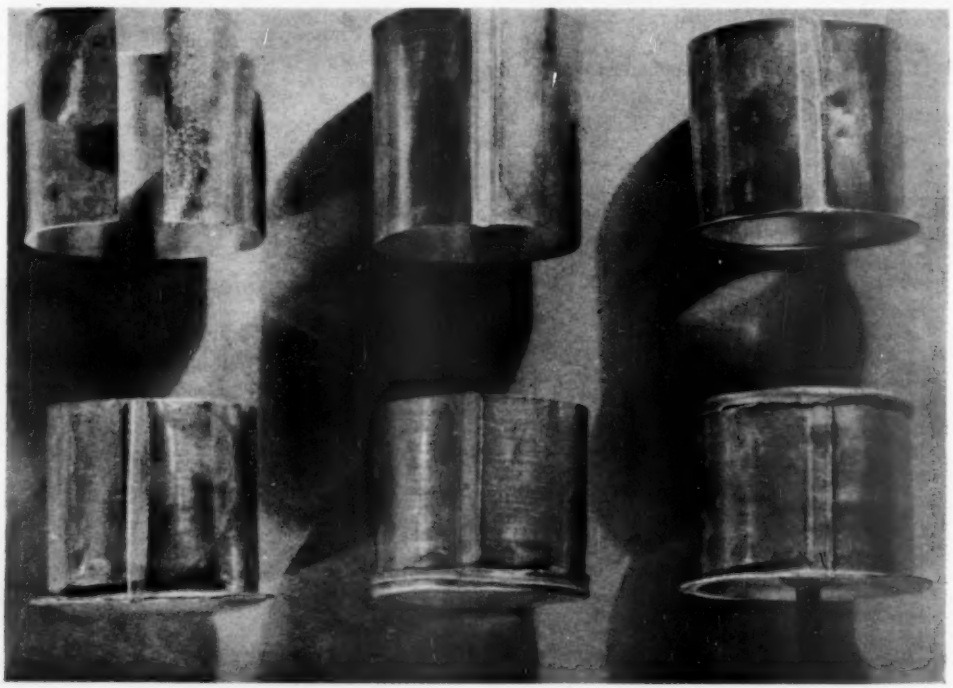

Fig. 18 Hot-pressure-welded aluminum capacitor cans in various stages of completion

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Resistance Variations During Spot Welding

Survey of resistance variations in the formation of spot welds in low-carbon steel, stainless steel and aluminum 3S alloy including the electrical conduction of various contacts and methods for the measurement of resistance

by W. L. Roberts

INTRODUCTION

THE total quantity of heat developed in a workpiece during the formation of a spot weld is a function of the work resistance. A knowledge of the variations of this parameter during the formation of the weld is therefore of interest and importance. In practice, these variations have been ignored because of the lack of suitable instrumentation for their measurement.

The purpose of this paper is to acquaint the reader with simple and readily available techniques for the measurement of resistance, and to present, in qualitative terms, a survey of resistance variations encountered in the formation of spot welds at 60 cps. welding current frequency, including the electrical conduction of various contacts.

It is common practice to regard both the resistance of the workpiece and the welding current as though they were constant in magnitude. If such were the case, the total quantity of heat, Q, developed in the workpiece is given by the product of the current squared, resistance and time:

$$Q = I^2 r_w T \text{ (joules)}$$
$$= 0.239\, I^2 r_w T \text{ (calories)}$$

where

I = the rms current, in amps.
r_w = the resistance of the workpiece, in ohms.
T = the duration of the flow of current, in secs.

If, however, the resistance is varying but the current remains constant, the total quantity of heat Q is given by the product of the current squared and the instantaneous resistance integrated with respect to time:

$$Q = I^2 \int_0^T \alpha(t)\, dt$$

where $\alpha(t)$ is the instantaneous resistance which is varying with time.

It will be shown that resistance variations of the workpiece may cause variations in the welding current amplitude. Under such circumstances, the total quantity of heat Q is given by the integral of the product of the instantaneous current squared and the instantaneous resistance with respect to time:

$$Q = \int_0^T \beta^2(t)\alpha(t)\, dt$$

where $\beta(t)$ is the current expressed as a function of time and, as will be seen later, is also a function of the electrical characteristics of the secondary circuit of the welder. It becomes apparent, therefore, that the workpiece resistance is important in the study of spot-weld formation and a better knowledge of its variation during the growth of a spot weld can contribute to the development of better spot-welding practices, and to improved welding controls.

DEFINITION OF TERMS

Instantaneous resistance is defined here as the ratio of the instantaneous value of the applied voltage to the current passing through a purely resistive conductor at the same instant in time.

Static resistance is the resistance encountered by currents of relatively small magnitudes which generate an insufficient quantity of heat within the resistive body to vary its value. Such resistance is usually measured by means of a d-c bridge which may provide a current for measurement purposes of the order of 1 ampere.

THE SECONDARY CIRCUIT OF THE WELDER

The secondary circuit of a 60-cps spot-welding machine is shown schematically in Fig. 1. It is seen to

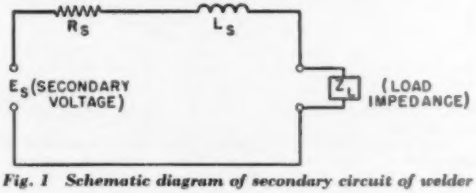

Fig. 1 Schematic diagram of secondary circuit of welder

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consist of an a-c voltage source E_s, a resistance R_s, and inductance L_s, and a load impedance Z_L. The first three items are dependent upon the design of the welder and the fourth is a function of the nature of the workpiece.

The use of phase shift heat control circuits produces welding currents that are not sinusoidal except for conditions of maximum current with a given transformer ratio and therefore contain harmonics of frequencies higher than 60 cps. For a balanced current waveform, i.e., a waveform in which the half-cycle impulses of opposite polarities are identical in magnitude and shape, these harmonics are predominantly odd, but for an unbalanced waveform, even ones are also present. The resistive component R_s, therefore, varies not only with the setting of the throat depth of the machine but, due to skin effect, also varies with the frequency of the secondary voltage E_s and the frequencies of its harmonics. The inductance of the throat, too, depends not only on its physical dimensions, but also on the presence of magnetic material placed between the electrodes to be spot welded. Thus it may be realized that the output impedance of the welder depends on:

(*a*) The setting of the heat control.
(*b*) The physical nature of the throat of the machine.
(*c*) The magnetic characteristics of the materials in the throat of the welder.

The impedance of the electrical load of the machine may be regarded as purely resistive only where a single spot weld is to be made in nonmagnetic materials. For low-carbon steel and other magnetic materials, or where current shunting due to adjacent welds is encountered, the load impedance may be partially inductive. In most cases, in so far as welding is concerned, the inductive component of the impedance is usually so small that it may be disregarded, but it must be considered when making instantaneous resistance measurements.

WELDING CURRENT FLUCTUATION DUE TO THE VARYING RESISTANCE OF THE WORKPIECE

It is desirable, from the viewpoint of electrical efficiency, to keep the output impedance of the secondary circuit of the welder as low as possible. However, the smaller the output impedance of the machine, the larger are the changes in the welding current produced by variations in the load resistance.

In the cases of aluminum and nonmagnetic stainless steel, the instantaneous resistance has been found, in these investigations, to remain fairly constant after the initial breakdown of contact resistance. This was not true for welds made in low-carbon steel, where, after the initial breakdown of the contact resistance, the weld resistance increased by approximately 70% and subsequently fell below its original value. Using a machine of low output impedance, such resistance

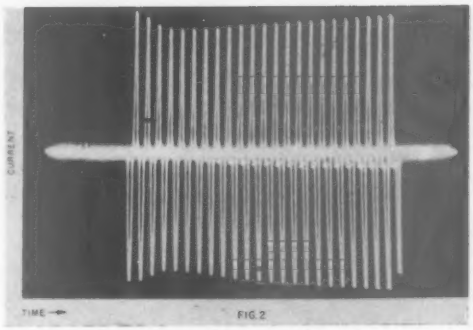


Fig. 2 Current oscillogram for spot weld in 0.125–0.125-in. low-carbon steel. 50-kva. welder. Approximate rms. current = 13.5 ka.

changes will have a pronounced effect on the current amplitude and consequently on the amount of heat energy generated in the workpiece. Under such conditions and in the absence of an accurate current regulator, it is improper to specify a constant welding current for low-carbon steel since the welding current and the rate of energy input into the load during the weld time are changing in a manner dependent upon both the machine and the load characteristics. This is illustrated by Fig. 2.

METHODS OF MEASUREMENT

(*a*) *Static Resistance*

Static resistance measurements were made by the use of a Kelvin bridge in the absence of welding current. The bridge circuit is shown schematically in Fig. 3. To enable the measurements to be made, small copper straps were brazed to the electrodes and the leads of the bridge were connected to them as shown in Fig. 4. With the head of the machine up, i.e., with no workpiece clamped between the electrodes, the bridge measures the resistance of the secondary circuit. When the workpiece is inserted under force between the

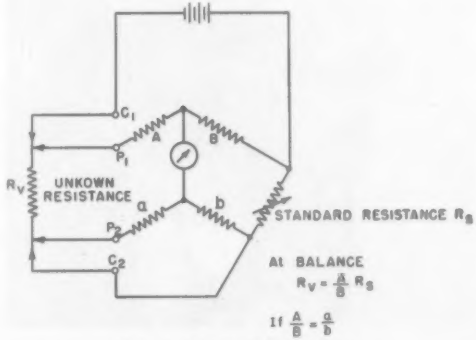


Fig. 3 Kelvin double bridge

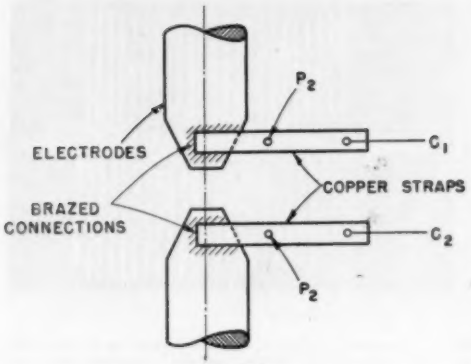


Figure 4

electrodes, the measured resistance is the load resistance shunted by the secondary resistance, R_s. The load resistance, r_w, is given by the equation:

$$r_w = \frac{R_m R_s}{R_s - R_m}$$

where

R_m = the measured resistance.
R_s = the welder secondary circuit resistance.

(b) *Instantaneous Resistance*

Instantaneous resistance values were computed from voltage and current oscillograms recorded photographically from a double beam cathode-ray oscilloscope with calibrating circuits. The films were studied as projected by a microfilm viewer. The current oscillograms were obtained by the use of an iron-cored toroid with its output terminals connected into a 1-ohm load or by means of an air-cored toroid and integrating circuit.[1] The iron-cored toroid was the less satisfactory due to its tendency to saturate.

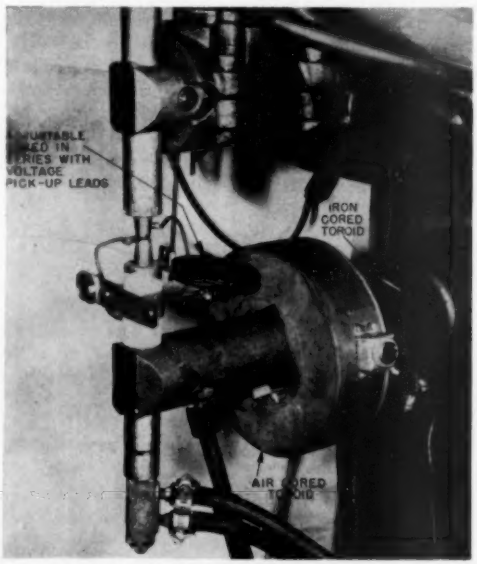


Figure 5

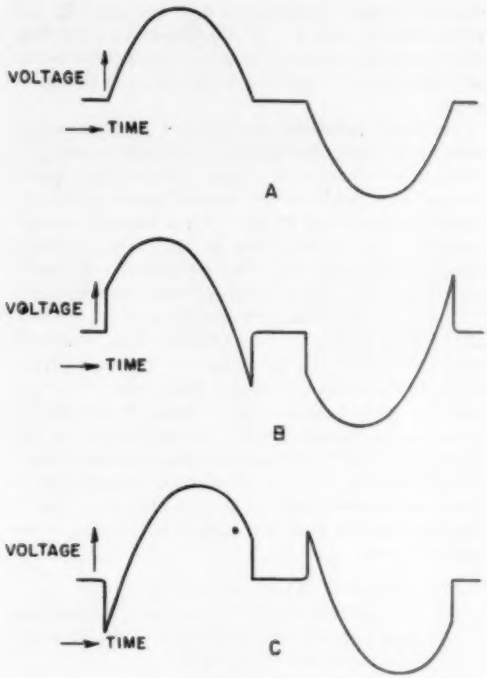


Figure 6

Instantaneous current values were calculated as follows: with the iron-cored toroid connected to the amplifier of the oscilloscope and the latter having a deflection sensitivity of X in. per volt and the toroid a turns ratio of $N:n$, the over-all sensitivity of the system was 1000 nX/N inches per ka. When the air-cored toroid, with a mutual inductance M (henries) and an integrating circuit of R (ohms) and C (farads), was used with the deflection sensitivity of the amplifier set at X in. per volt, the over-all sensitivity of the system was 1000 MX/RC in. per ka.

When measuring the voltage developed across the load of the welder, care must be taken to insure that any mutual inductive coupling between the pick-up leads and the secondary circuit of the welder is compensated. To accomplish this, a movable coil was located in the throat of the welder (Fig. 5) and wired in series with one of the pick-up leads which were connected to the ends of the electrodes. This coil was orientated so that the induced voltage appearing across its terminals was equal and opposite to that induced in the leads. Correct adjustment of the coil was best accomplished by setting the heat control at a low value, inserting a specimen of nonmagnetic material between

the electrodes, and adjusting the coil until a voltage trace as shown in Fig. 6 (*A*) was obtained. Incorrect adjustment resulted in traces as shown in Figs. 6 (*B*) and 6 (*C*).

When obtaining voltage and current oscillograms, the two beams of the oscilloscope utilized the same time-base which insured correct phasing of the two waveforms. Due to slight imperfections in the cathode-ray tube, the vertical deflection sensitivity of the two beams of the instrument varied slightly along the time-base, but the error in resistance measurement due to this effect was of the order of 2%. The time-base length should be adjusted to be as long or slightly longer than the duration of the waveform to be studied, and was synchronized to the line frequency, 60 cps. Such synchronization resulted in oscillograms which did not always begin at the beginning of the sweep, but this was of no importance since the first and last cycles of the oscillograms were easily identified by observation. The oscilloscope time-base speed could be slowed down to record about 30 cycles of current and voltage. If recordings were to be made for longer weld times, it would have been preferable to use a magnetic oscillograph. In this case, an amplifier would have been required to drive the galvanometer recording the current waveform if the air-cored toroid were to be used as a pick-up device.

Since it was possible some confusion could arise as to the identification of the two oscillograms when recorded, the two time bases of the instrument were slightly separated and one trace used consistently for the voltage and the other for current. Identification was also made easier by setting the two sweeps at different intensity settings and marking the face of the cathode-ray tube.

(c) *Reactance of the Workpiece*

When the impedance of the workpiece is purely resistive and of a constant value, the voltage and current oscillograms are identical in shape. If, however, an inductive reactance forms part of the impedance, then the voltage oscillogram is characterized by a steeply rising slope at the front edge of each half-cycle waveform and a steeply falling slope at the trailing edge. This is shown diagrammatically in Fig. 7.

The ratio of the amplitude of this "step" occurring at the beginning of the oscillogram, expressed in volts, to the rate of rise of current, expressed in amperes per second, gives the inductance in henries. This reactance expressed in ohms at a frequency of 60 cps. is $120\pi L_w$ ohms where L_w is the inductance in henries.

Usually, however, the effect of the reactance on the impedance is negligible. For example, in the case of a single thickness of low-carbon steel $^1/_8$ in. thick, after the breakdown of contact resistance, the instantaneous value of the resistance reached a minimum of approximately 125 microhms, whereas the reactance at 60 cps. was found to be 19.2 microhms, producing an impedance increase of 1.0%.

WELDING EQUIPMENT USED

Throughout the experiments, an air-actuated, press-type 50-kva. welder was used with a synchronous control panel. The welder was provided with a transformer having eight primary taps, giving a secondary voltage output on no load of 3 to 6 v. rms.

The control panel was provided with facilities to enable any desired number of current impulses to be applied to a workpiece.

Three different types of metal were used, namely,

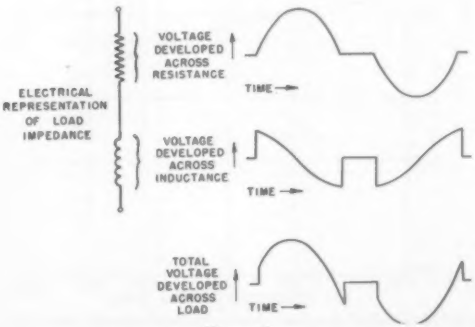


Figure 7

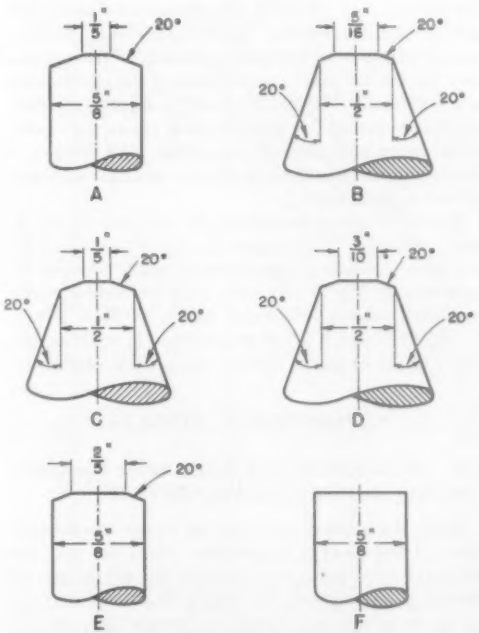


Fig. 8 Electrode tip contours

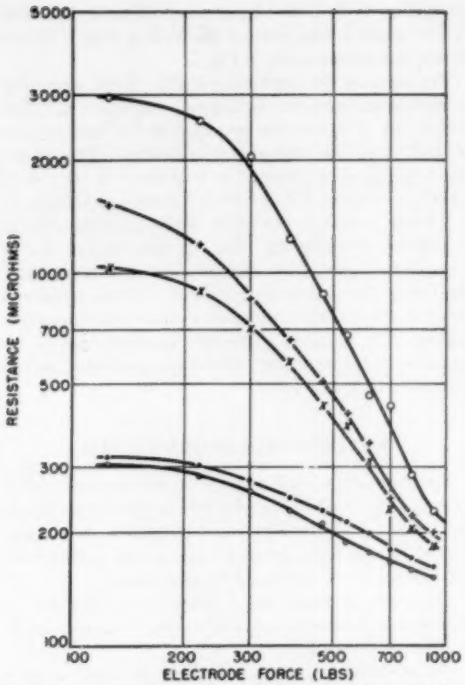


Fig. 9 Variation of resistance with electrode force for five single pieces of 1/8-in. aluminum sheet

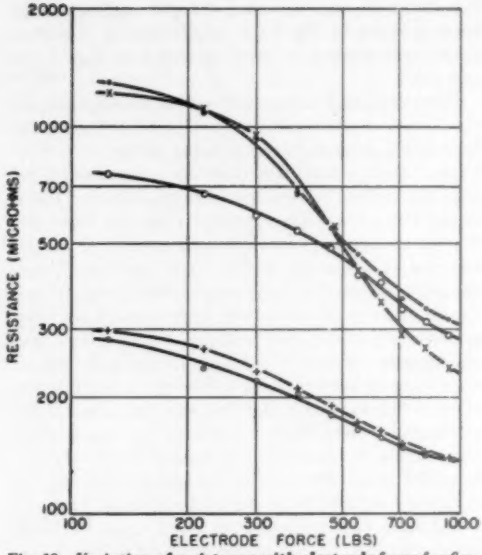


Fig. 10 Variation of resistance with electrode force for five single pieces of 1/8-in. aluminum sheet

low-carbon steel, 18 Cr–8 Ni annealed stainless steel and 3S aluminum alloy. Since the investigations described herein were intended to be only of an exploratory nature, the exact compositions of the metals were not determined. However, in all comparative tests, the same piece of metal or identical pieces were used. Such pieces were cleaned with either steel wool or a wire wheel and no chemical cleaning methods were employed in these tests.

Electrode tips of several shapes, as shown in Fig. 8, were employed. Those shown in Fig. 8 (*A*) were used for static resistance measurements, while contours illustrated by Fig. 8 (*B*) were used for instantaneous resistance studies. Contours shown in Figs. 8 (*C*), 8 (*D*), 8 (*E*) and 8 (*F*) were employed in studying the effect of the apparent contact areas of the electrodes.

EXPERIMENTAL RESULTS

(a) *The Resistance of a Single-Sheet Workpiece During the Squeeze or Preweld Time*

When the upper electrode of the welder was brought down slowly onto a single-sheet workpiece and the electrode force increased gradually by adjustment of the air pressure above the piston, the d-c resistance of the workpiece was found to decrease in a smooth manner with increasing electrode force. Such resist-

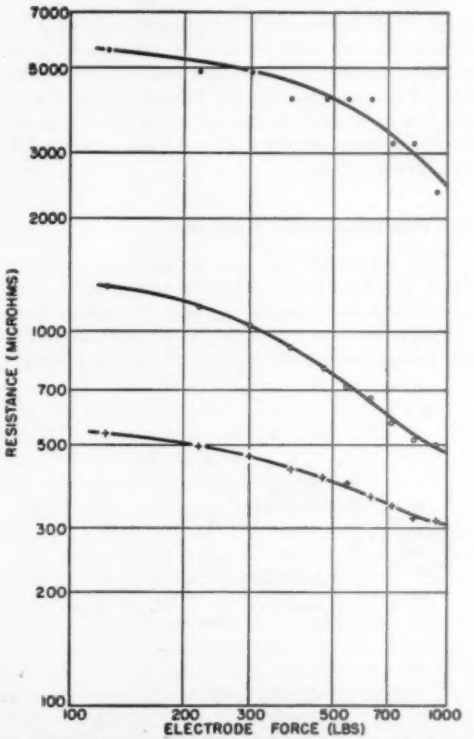


Fig. 11 Variation of resistance with electrode force for three single pieces of 3/8-in. aluminum sheet

ance-force curves for various thicknesses of single sheets of aluminum using electrodes as shown in Fig. 8 (*A*) are shown in Figs. 9, 10 and 11. If, however, at various cylinder pressures, the head of the welder is brought down under full impact on aluminum, a resistance-force curve as shown in Fig. 12 is produced. The different resistance-force curve so obtained is probably due to the mechanical characteristics of the welder and may be different for other machines.

Resistance-force curves for $^1/_{16}$-in. specimens of stainless steel and low-carbon steel utilizing the same electrodes with slowly increasing piston pressures are shown graphically in Figs. 13 and 14, respectively.

It is a general belief that contact resistance is the resistance of a film of oxide or of foreign matter between two metals in contact. However, since contact resistance does not have the characteristics of the resistance of a semiconductor but behaves like a metallic or pure resistance,[2] current flow between the metals does not have a uniform density across the two surfaces placed in close proximity to each other (the apparent contact area) but must occur along localized metallic paths. The apparent effect of a poorly conducting film between the metallic surfaces is believed to be the result of a reduction in the number of microscopic zones of contact.[3] Thus contact resistance is determined solely by the geometric deformation of the lines of current flow near the contact and occurs within small zones adjacent to the contacts.

The resistance values obtained in these experiments for single sheets of metal are the combination of:

(*a*) The resistances of the ends of the electrode tips.
(*b*) The "bulk" or internal resistance of the workpiece.
(*c*) The resistance at the two contacts.

The components (*a*) and (*b*) should be sensibly inde-

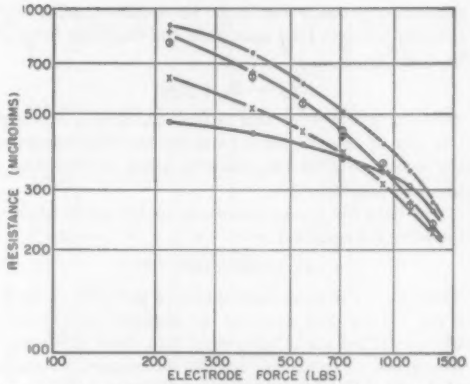


Fig. 13 Variation of resistance with electrode force for five single pieces of $^1/_{16}$-in. stainless steel

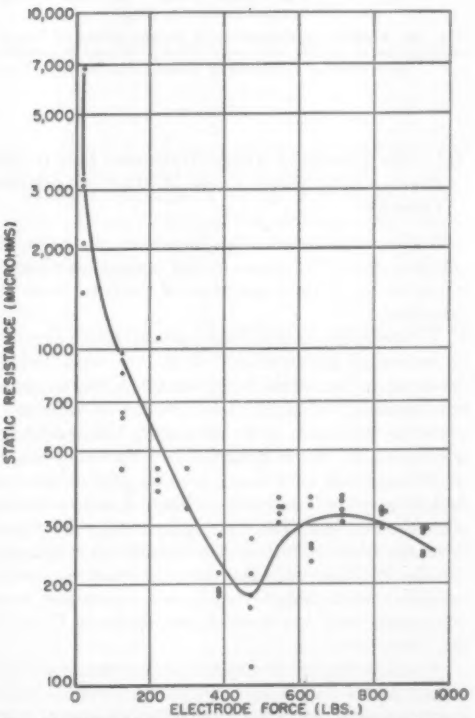


Fig. 12 Curve showing variation of resistance with force for $^1/_{16}$-in. aluminum under impact

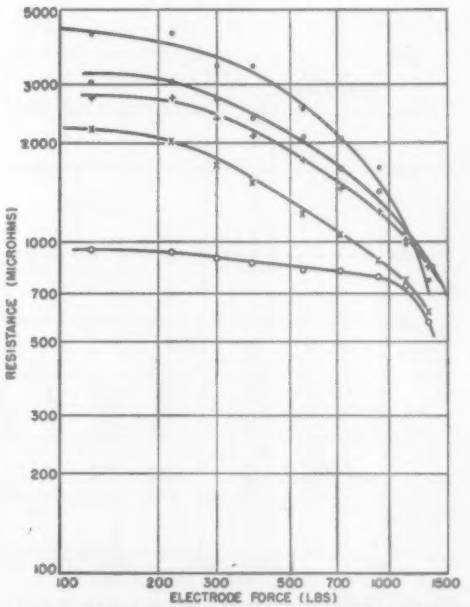


Fig. 14 Variation of resistance with electrode force for five single pieces of $^1/_{16}$-in. low-carbon steel

pendent of pressure and hence we should expect a relationship between load resistance and electrode force to be of the form

$$r_w = R_0 + f(p)$$

where r_w is the total load resistance, R_0 is a constant (the sum of components (a) and (b)) and $f(p)$ represents the resistance of the two contacts, which is a function of the electrode force (p).

The data for $^1/_{16}$-in. aluminum under slowly applied force fits the equation

$$r_w = R_0 + e^{k(1-ap)}$$

where R_0, k and a are constants for a given set of conditions. If the two contacts are regarded as identical, the results are not in agreement with those of Contius[4] who gives an empirical formula for contact resistance of the form

$$r_c = k/p^n$$

where R_c is the contact resistance, k is a constant and n has a value between $^1/_2$ and 2, dependent upon the type of contact and the finish of the contacting surfaces.

Generally speaking, the resistance force data may be summarized as follows:

1. At low electrode forces, the measured resistance of apparently identical specimens may differ widely (by as much as 10:1).
2. The higher the resistance at low forces, the greater the rate of decrease of resistance with force.
3. At high forces, there is a closer uniformity between measured resistance values.

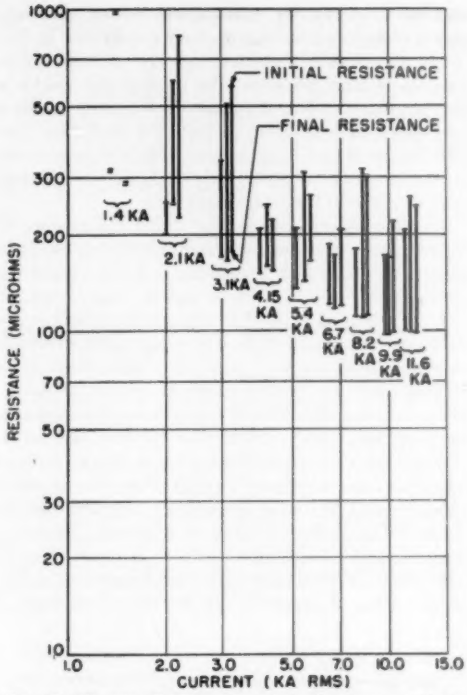


Fig. 16 Change of resistance of single pieces of $^1/_{16}$-in. aluminum at 230-lb. electrode force produced by single-cycle current impulses of various rms values

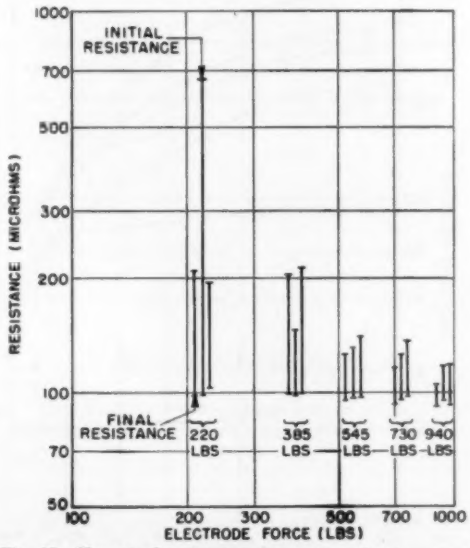


Fig. 15 Change of resistance due to 1 cycle of current (10 ka.) at various electrode forces for single pieces of $^1/_{16}$-in. aluminum

(b) *The Change of Static Resistance Due to the Passage of a Single Cycle of High Magnitude Current*

An investigation into the breakdown of contact resistance caused by pressure and current was undertaken on $^1/_{16}$-in. thick specimens of the three materials described.

The first test involved the passage of a single cycle of current of approximately 10 ka rms. with various electrode forces. The d-c resistance of the specimen was measured before and after the flow of the current with the specimen under pressure. The results for aluminum are shown graphically in Fig. 15. The effect of electrode force is largely masked by the passage of high magnitude currents. Change of resistance with current for a single sheet of $^1/_{16}$-in. aluminum under a constant electrode force of 230 lb. is shown graphically in Fig. 16. Corresponding curves showing the results obtained with stainless steel and low-carbon steel specimens, both $^1/_{16}$ in. thick, are shown in Figs. 17, 18, 19 and 20.

From the figures, it is apparent that the greater the magnitude of the current impulse, the lower the measured resistance after the termination of current flow. It has been found that this resistance (r_w) is approxi-

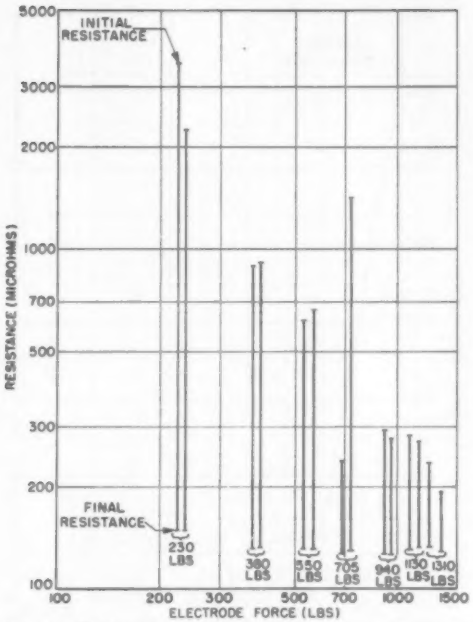


Fig. 17 Change of resistance due to 1 cycle of current (9 ka.) at various electrode forces for single pieces of $^1/_{16}$-in. stainless steel

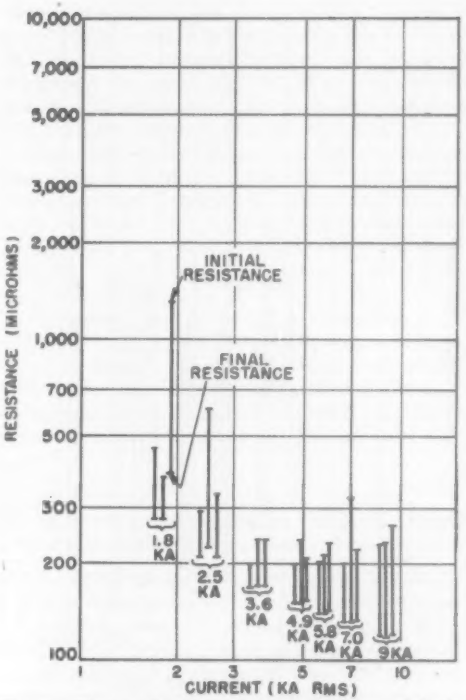


Fig. 18 Change of resistance of single pieces of $^1/_{16}$-in. stainless steel at 300-lb. electrode force produced by single-cycle current impulses of various rms values

mately proportional to the reciprocal of the peak current, thus

$$r_w = R_0 + \frac{K}{I_p}$$

where R_0 and K are constants for a given material and set of conditions, and I_p is the peak current.

The static resistance of a single sheet of metal is not further reduced by the application of additional current impulses of the same magnitude, at widely spaced time intervals, Fig. 21.

(c) *Instantaneous Resistance Changes during the First Half Cycle of Current Flow*

As previously stated, instantaneous resistance measurements were made from recordings of the voltage and current oscillograms. For reasons of accuracy the duration of the oscilloscope sweep was set to $^1/_{60}$ sec. when studies were to be made of the change of resistance during the first half cycle. Examples of such oscillograms for a single sheet of $^1/_{16}$-in. aluminum are shown in Fig. 22, and as described under "Methods of Measurements," the start of the oscillograms sometimes occurred approximately half way along the time base. Curves showing variation of instantaneous resistance with time for aluminum during the first half cycle are shown in Fig. 23 for various currents.

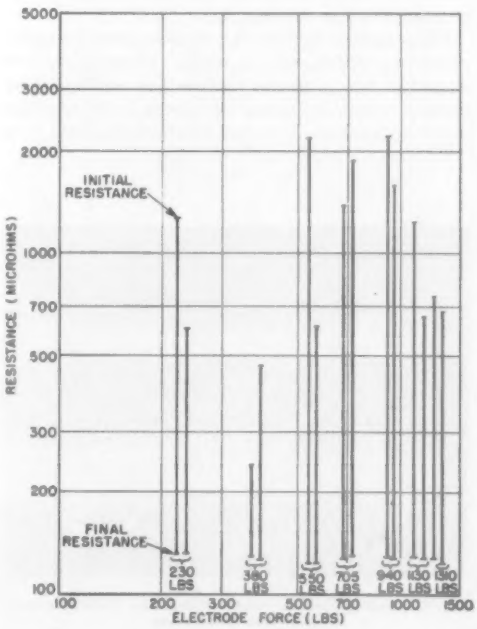


Fig. 19 Change of resistance due to 1 cycle of current (8.7 ka.) at various electrode forces for single pieces of $^1/_{16}$-in. low-carbon steel

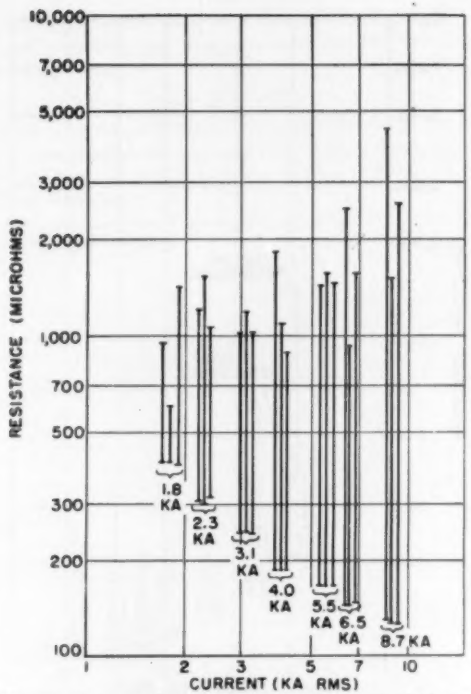


Fig. 20 Change of resistance of single pieces of $^1/_{16}$-in. low-carbon steel at 300-lb. electrode force produced by single-cycle current impulses of various rms values

Similar curves for stainless steel and low-carbon steel are shown in Figs. 24 and 25.

These curves showing the instantaneous resistance variation with time are of interest. When the data are plotted in such a manner to show the variation of resistance r_w with instantaneous current, I, the resultant curves approximate rectangular hyperbolas of the form

$$r_w - R_0 = \frac{K}{I}$$

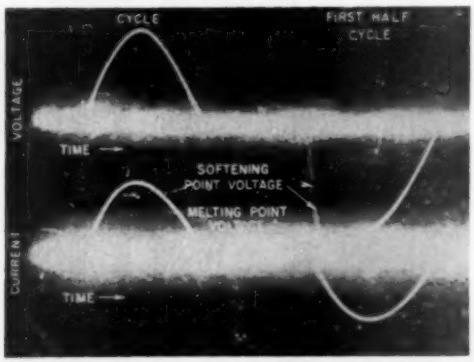


Fig. 22 Voltage and current oscillograms for single sheet of $^1/_{16}$-in. aluminum

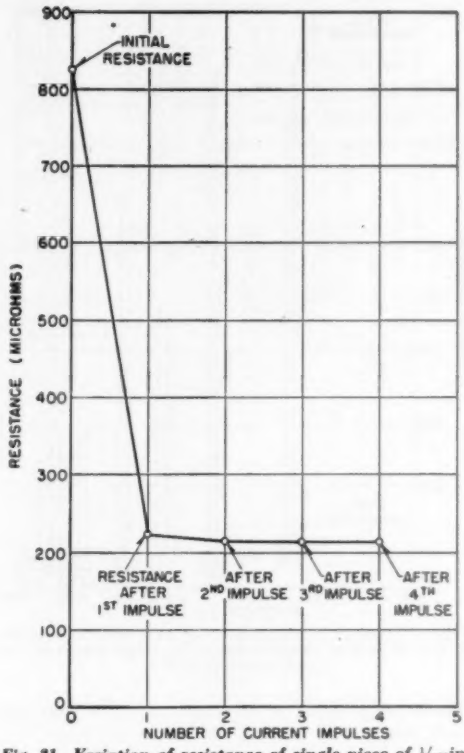


Fig. 21 Variation of resistance of single piece of $^1/_{16}$-in. aluminum sheet after application of discrete single-cycle impulses of current with an rms value of 3.1 ka.

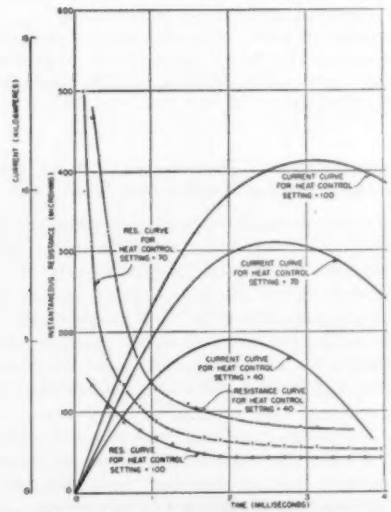

CURRENT CURVE FOR HEAT CONTROL SETTING = 100
RES. CURVE FOR HEAT CONTROL SETTING = 70
CURRENT CURVE FOR HEAT CONTROL SETTING = 70
CURRENT CURVE FOR HEAT CONTROL SETTING = 40
RESISTANCE CURVE FOR HEAT CONTROL SETTING = 40
RES. CURVE FOR HEAT CONTROL SETTING = 100

Fig. 23 Curves showing instantaneous resistance variation of single piece of $^1/_{16}$-in. aluminum sheet for various current waveshapes during the first half cycle of current flow. 50-kva. welder. Tap No. 1. Electrode force = 300 lb.

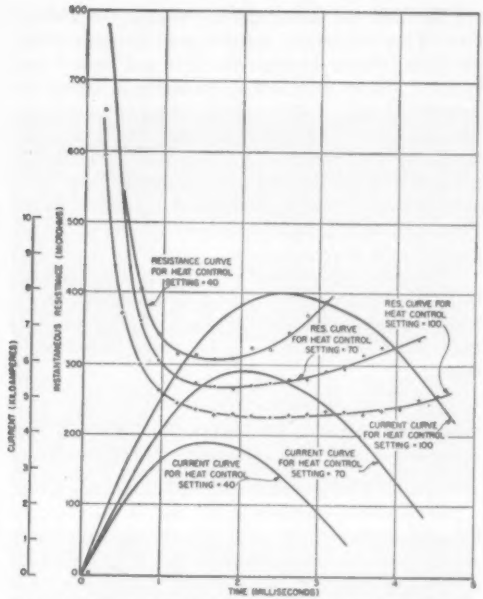

CURRENT (KILOAMPERES)
INSTANTANEOUS RESISTANCE (MICROHMS)
TIME (MILLISECONDS)
RESISTANCE CURVE FOR HEAT CONTROL SETTING = 40
RES. CURVE FOR HEAT CONTROL SETTING = 100
RES. CURVE FOR HEAT CONTROL SETTING = 70
CURRENT CURVE FOR HEAT CONTROL SETTING = 100
CURRENT CURVE FOR HEAT CONTROL SETTING = 70
CURRENT CURVE FOR HEAT CONTROL SETTING = 40

Fig. 24 Curves showing instantaneous resistance variation of single piece of $^1/_{16}$-in. stainless steel sheet for various current waveshapes during the first half cycle of current flow. 50-kva. welder. Tap No. 1. Electrode force = 300 lb.

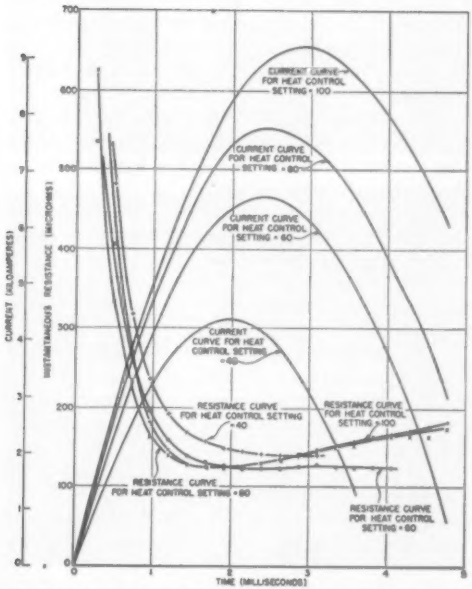

CURRENT (KILOAMPERES)
INSTANTANEOUS RESISTANCE (MICROHMS)
TIME (MILLISECONDS)
CURRENT CURVE FOR HEAT CONTROL SETTING = 100
CURRENT CURVE FOR HEAT CONTROL SETTING = 80
CURRENT CURVE FOR HEAT CONTROL SETTING = 60
CURRENT CURVE FOR HEAT CONTROL SETTING = 40
RESISTANCE CURVE FOR HEAT CONTROL SETTING = 40
RESISTANCE CURVE FOR HEAT CONTROL SETTING = 100
RESISTANCE CURVE FOR HEAT CONTROL SETTING = 80
RESISTANCE CURVE FOR HEAT CONTROL SETTING = 60

Fig. 25 Curves showing instantaneous resistance variation of single piece of $^1/_8$-in. thick low-carbon steel sheet for various current waveshapes during the first half cycle of current flow. 50-kva. welder. Tap No. 1. Electrode force = 300 lb.

where k varies from metal to metal, where R_0 may be considered to be the bulk resistance of the workpieces and electrodes. Although different current waveshapes were employed, Figs. 23, 24 and 25, the relationship still held closely. The decrease of resistance with increasing current is not reversible, however.

This formula in effect means that while the current is increasing, during the first half cycle, there is nearly a constant voltage developed across the contacts (the contact voltage). For both contacts in series, these voltages have been found to be 0.5 v. for $^1/_{16}$-in. aluminum, 0.89 v. for $^1/_8$-in. low-carbon steel and 1.0 v. for $^1/_{16}$-in. stainless steel.

It is believed that these voltages correspond to the sum of the melting point voltages of the contacts, described by Holm.[6] Careful examination of the voltage oscillograms also show discontinuities occurring at lower potentials (see Fig. 22) and these are believed to correspond to the sum of the softening point voltages.[5]

(d) Instantaneous Resistance Variation During the Second Half Cycle of Current Flow

It has been generally assumed that contact resistance is broken down during the first half cycle of current flow and that thereafter, during the creation of the weld, only the increases in nugget diameter, temperature and plasticity of the metals affect the measured instantaneous resistance. This is illustrated for aluminum by Fig. 26. It appears, however, that in some cases the contact resistance has to be broken down for both directions of current flow. This is indicated by

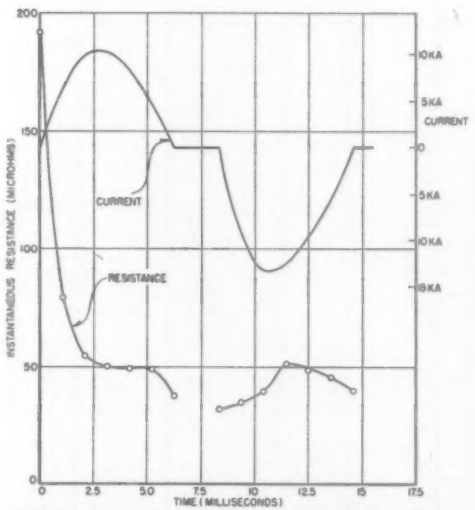


Fig. 26 Curves showing variation of instantaneous resistance during 1 cycle current flow for single sheet of aluminum $^1/_{16}$ in. thick. Electrode force = 300 lb. Tap No. 1. Heat control setting = 80. 50-kva. welding machine

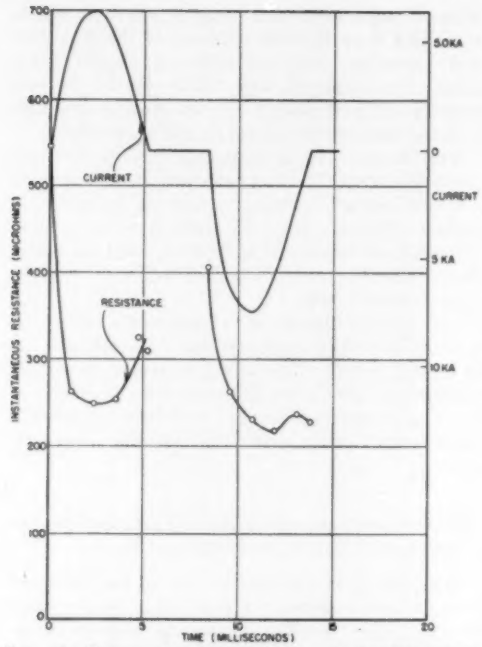


Fig. 27 Curves showing variation of instantaneous resistance during 1 cycle current flow for single sheet of stainless steel 1/10 in. thick. Electrode force = 300 lb. Tap No. 1. Heat control setting = 80. 50-kva. welding machine

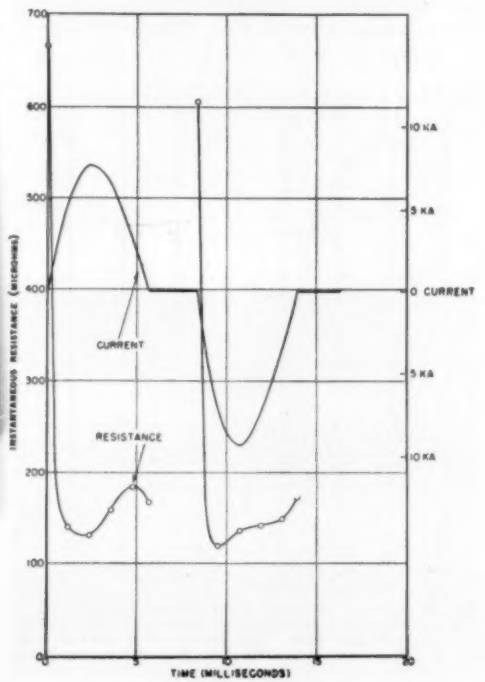


Fig. 28 Curves showing variation of instantaneous resistance during 1 cycle current flow for single sheet of low-carbon steel 1/3 in. thick. Electrode force = 300 lb. Tap. No. 1. Heat control setting = 80. 50-kva. spot welding machine

the fact that the instantaneous resistance of a single sheet of low-carbon and stainless steel increases during the time interval between the first and second half cycles of current flow and again decreases during the second half cycle. This was not found for aluminum. This is evident from Figs. 26, 27 and 28, showing the instantaneous resistance variation with time during the first complete cycle for aluminum, stainless steel and low-carbon steel. These effects may also be seen by a study of Fig. 29 showing photographs of oscillograms for the three materials.

In the case of aluminum, a unique effect is sometimes found in which the second half cycle voltage waveform is approximately triangular as seen in Fig. 29, while the half cycle current waveform is closely sinusoidal in shape.

(e) *Instantaneous Resistance Variation Across Individual Contacts During the First Two Cycles of Current Flow*

The resistance variation across each of the two contacts formed by a single piece of aluminum and the two copper alloy electrodes was investigated. To simplify the investigation, the resistance of each contact was measured only at the beginning and end of each half cycle of current flow. The results for 0.020-in. aluminum, using tips as shown in Fig. 8 (*B*), with an electrode force of approximately 700 lb. and an rms current of approximately 13,000 amp. are shown in Fig. 30. These results are typical for various thicknesses of the metal and various currents. The ratios of the resistances of the two contacts at the beginning and end of each current impulse are shown in Fig. 31.

A study of the curves, Figs. 30 and 31, reveal the following:

1. At the beginning of the first half cycle of current flow, the contact at which the electrode is negative with respect to the aluminum was found to have a lower resistance than the other contact.

2. The decrease in resistance due to the first half cycle of current flow is greater at the contact where the electrode is positive with respect to the metal.

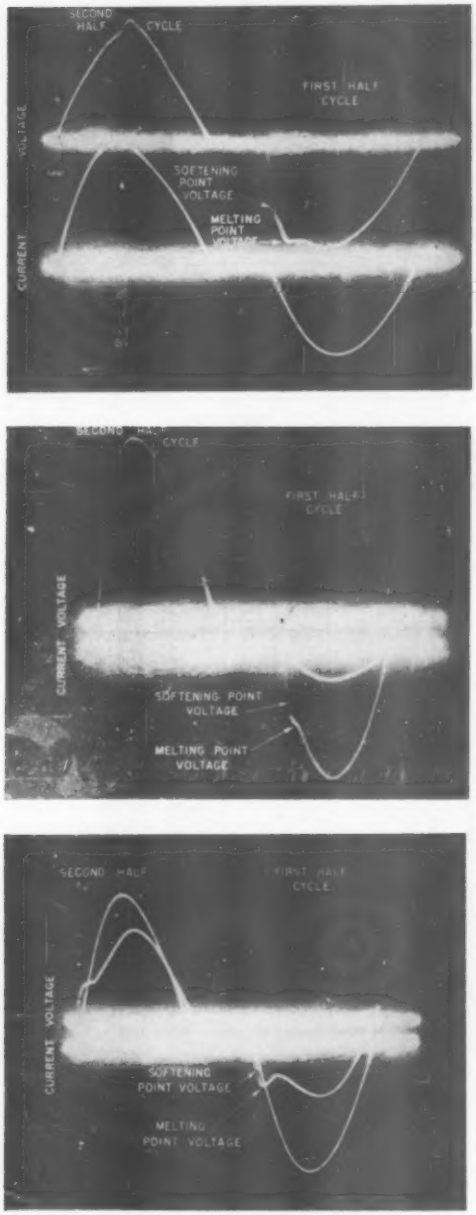
3. At the end of the first half cycle, the contact at which the initial resistance was larger, has the lower resistance.

4. At the beginning of the second half cycle, the contact which had the lower resistance at the end of the first half cycle of current, electrode positive with respect to aluminum, appears to have increased its resistance and vice versa.

5. During the second half cycle, the contact at which the electrode is negative with respect to the aluminum suffers the greater change of resistance.

Similar results have been found to occur, to a less

noticeable degree, with both stainless and low-carbon steels.



(a) 1/10-in. aluminum sheet
(b) 1/10-in. stainless steel sheet
(c) 1/10-in. low-carbon steel sheet

Fig. 29 Voltage and current oscillograms for single sheets of aluminum, stainless steel and low-carbon steel

(f) Instantaneous Resistance Variation Throughout the Entire Duration of Welding Current Flow

For such measurements, low sweep speeds were used with the oscilloscope, and examples of such traces are shown in Fig. 32. Resistance computations were made

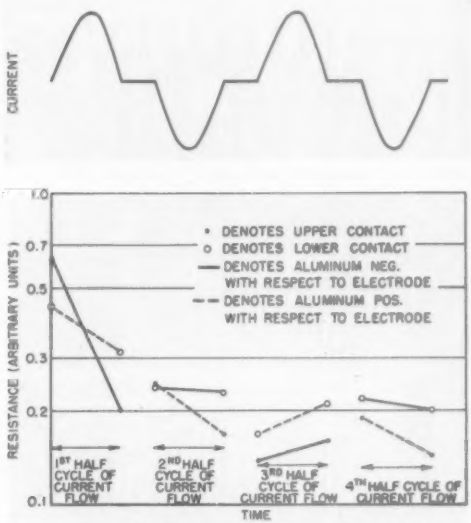


Fig. 30 Simplified diagram showing varying resistance of two contacts (aluminum-copper alloy) at the beginning and end of current impulses

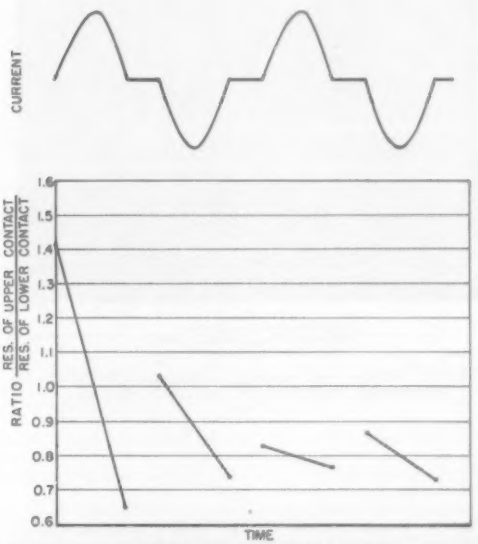
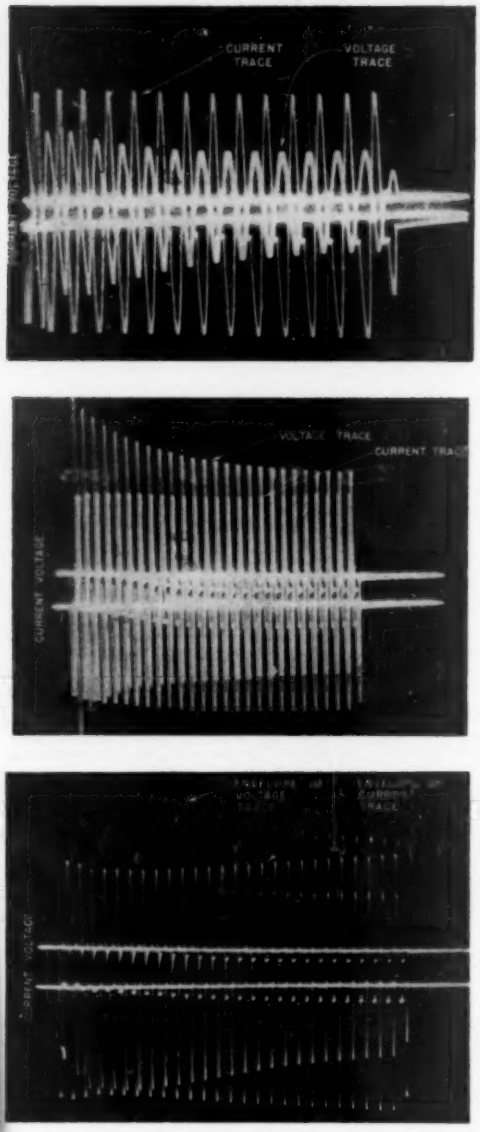


Fig. 31 Simplified diagram showing ratio of resistance of two contacts (aluminum-copper alloy) at the beginning and end of current impulses



0.025–0.025-in. aluminum
0.064–0.064-in. stainless steel
0.064–0.064-in. low-carbon steel

Fig. 32 Voltage and current oscillograms for welds in aluminum, stainless steel and low-carbon steel

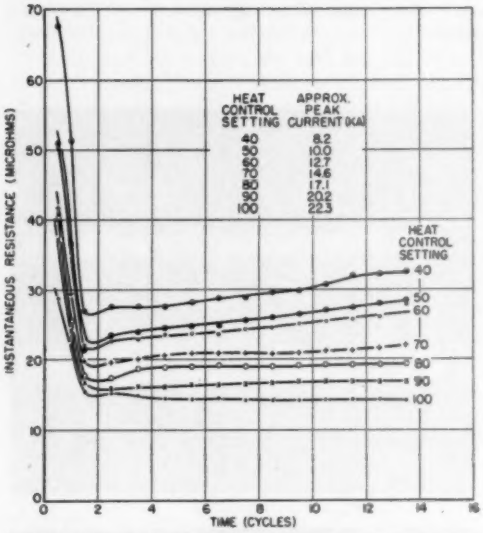


Fig. 33 Curves showing instantaneous resistance variation with time of a spot weld in 0.025–0.025-in. aluminum for various heat control settings of a 50-kva. welding machine. Tap No. 6. Electrode pressure = 385 lb. (Electrodes cleaned after each weld)

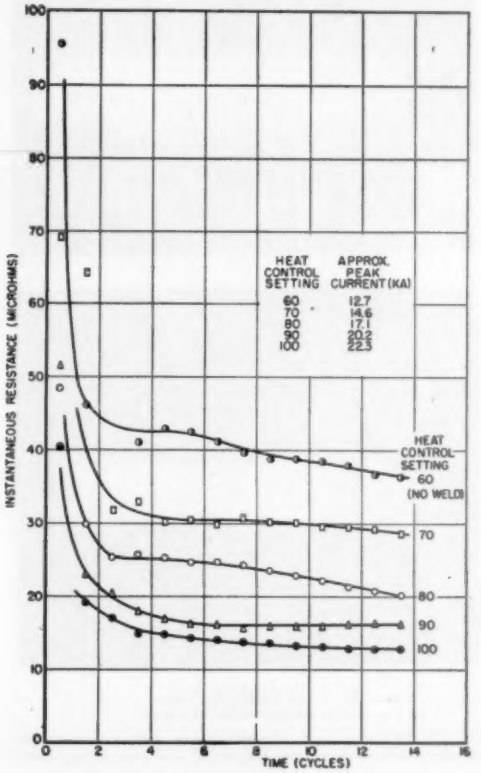


Fig. 34 Curves showing instantaneous resistance variation with time of a spot weld in 0.025–0.025-in. aluminum for various heat control settings of a 50-kva. welding machine. Tap No. 6. Electrode force = 385 lb. (Contaminated electrodes)

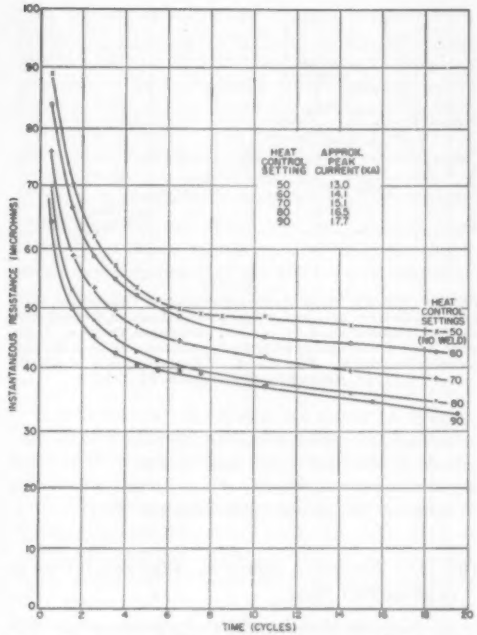


Fig. 35 Curves showing instantaneous resistance variation with time of a spot weld in 0.064–0.064-in. stainless steel for various heat control settings of a 50-kva. welding machine. Tap No. 6. Electrode force = 1400 lb.

using only peak values of voltage and current obtained from the oscillograms.

Results obtained for welds made between two sheets of 0.025-in. aluminum at 385 lb. electrode force are shown in Fig. 33, the electrodes being cleaned after each weld was made. It will be noticed that after the initial breakdown of the contact resistance, the resistance showed a tendency to increase uniformly with time, especially at lower currents. For aluminum-contaminated electrodes, results as shown in Fig. 34 were obtained.

Stainless steel, Fig. 35, showed a similar trend in that the resistance continually decreased with time.

The results obtained with low-carbon steel, Fig. 36, exhibited the following interesting characteristics:

1. For any current, the resistance first rapidly decreased, reached a transitory minimum, then increased to a peak and again decreased with continuity of time.
2. For decreasing current values:

(*a*) The transitory minimum instantaneous resistance value increases.

(*b*) The rate of rise of instantaneous resistance with time after the contact resistance has been broken down decreases.

(*c*) The maximum instantaneous resistance, following contact breakdown, increases until those currents which do not produce welds are reached and then this maximum again decreases.

(*d*) The rate of decrease of instantaneous resistance following the peak decreases.

(*e*) The resistance value at the end of the welding times used increases.

(*f*) The time taken to reach the maximum value of instantaneous resistance increases.

The rise in resistance after the breakdown of contact resistance is believed to be due to the heating of the

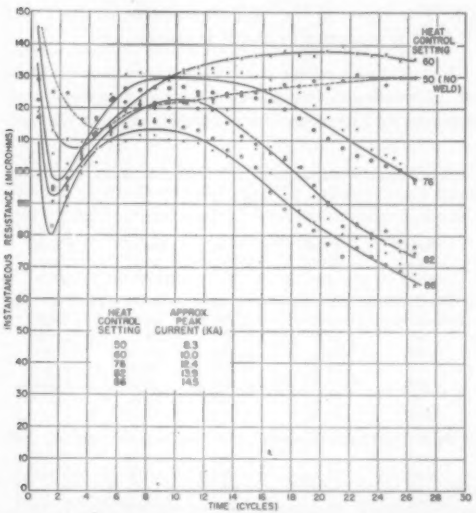


Fig. 36 Curves showing instantaneous resistance variation with time of a spot weld in 0.064–0.064-in. low-carbon steel for various heat control settings of a 50-kva. welding machine. Tap No. 4. Electrode force = 820 lb.

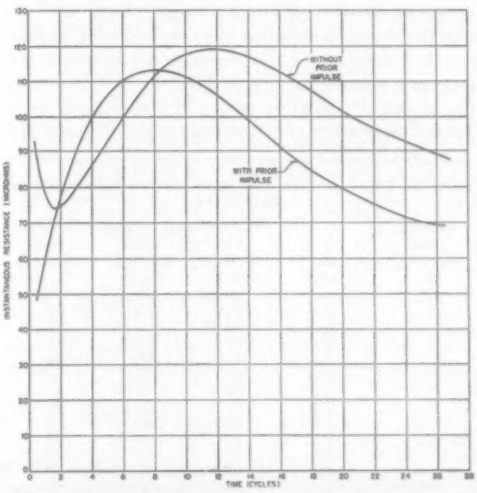


Fig. 37 Curves showing variation of instantaneous resistance with time for 0.064–0.064-in. low-carbon steel spot weld with and without 1-cycle current impulse prior to weld. Electrode force = 900 lb.

workpiece and the subsequent fall after the maximum resistance has been reached may be attributed to two causes; namely, the growth of the nugget diameter and the increasing penetration of the electrodes into the workpiece. Both produce increasing current carrying areas.

The application of a single-cycle current impulse prior to the main flow of welding current also produces some interesting effects, as shown in Fig. 37. Here it will be seen that with the application of the single-cycle impulse prior to welding:

(*a*) The initial resistance is lower than the transitory minimum obtained without the prior impulse.

(*b*) The rate of rise of resistance following the transitory minimum is greater.

(*c*) The peak instantaneous resistance is slightly lower.

(*d*) The time to reach the peak instantaneous resistance is appreciably less.

(*e*) The rate of decrease of resistance following the peak is greater.

(*f*) The final instantaneous resistance at current termination is smaller.

(*g*) *The Apparent Contact Area of the Electrodes*

The instantaneous resistance of a workpiece might appear to be almost inversely proportional to the apparent area of electrode contact with the plate where two identical electrodes are used. This, however, is not the case with low-carbon steel.

Four pairs of electrodes (Figs. 8 (*C*), 8 (*D*), 8 (*E*), and 8 (*F*)) were machined, having contacting circular ends 0.2, 0.3, 0.4 and 0.625 in. diameter, giving a 9:1 range of apparent contact area. Instantaneous resistance measurements using single sheets of $^1/_{32}$-, $^1/_{16}$- and $^1/_8$-in. low-carbon steel showed that increasing the contact area did decrease the instantaneous resistance values, but not in direct linear relationship to the apparent contact area. The measurements in Table 1 were made at the current peaks for each half cycle of a two-cycle period of current flow. The amplitude of the current was approximately 5 ka, and the electrode force 500 lb. These values were chosen to minimize the heating and indentation effects.

Table 1—Effect of Electrode Diameter on Instantaneous Resistance

Electrode end diameter, in.	*Half cycle*	*Instantaneous resistance, microhms* Sheet thickness, $^1/_{32}$ in.	Sheet thickness, $^1/_{16}$ in.	Sheet thickness, $^1/_8$ in.
0.2	1st	92.5	113	112.5
	2nd	73.5	103	102
	3rd	68.5	100	100
	4th	68	94.5	100
0.3	1st	77	104	93.5
	2nd	68	86	79.5
	3rd	59.5	87.5	77
	4th	59.5	85	80
0.4	1st	85	91	88.5
	2nd	72	75.5	76
	3rd	70	79	72.5
	4th	68	82	73.5
0.625	1st	71	91	89.5
	2nd	62	76.5	70.5
	3rd	64.5	71	68
	4th	61.5	73	68.5

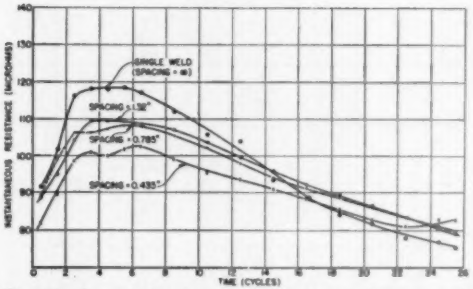


Fig. 38 Curves showing instantaneous resistance variation with time of a second spot weld made in 0.064–0.064-in. low-carbon steel at various distances from a single spot weld made under identical conditions with a 50-kva. welding machine. Tap No. 4. Electrode force = 820 lb. Heat control setting = 85

(*h*) *The Shunting Effect of Adjacent Welds in Low-Carbon Steel*

To study the shunting effect of adjacent welds, spot welds of various spacings were made, using $^1/_{16}$-in. low-carbon steel sheets. The instantaneous resistance-time curves for such welds are shown in Fig. 38. As would be expected, the closer a weld is made to a previously formed nugget, the less its maximum resistance but the higher its final resistance as compared to an isolated nugget.

(*i*) *The Effect of Current Magnitude on the Total Heat Generated in the Workpiece*

It was shown earlier that the greater the magnitude of the welding current flowing through the workpiece, the less its instantaneous resistance, due to the fact

Table 2

Heat control setting	*Peak current, ka*	*Peak voltage, v.*	*Resistance, microhms*	*Peak power input, watts*
0.025–0.025-in. aluminum spot weld data for 17th half-cycle				
40	8.2	0.241	29.5	1,980
50	10.0	0.261	26.1	2,610
60	12.7	0.312	24.6	3,960
70	14.6	0.303	20.8	4,410
80	17.1	0.326	19.1	5,560
90	20.2	0.331	16.4	6,690
100	22.3	0.318	14.3	7,100
0.064–0.064-in. stainless steel spot weld data for 13th half cycle				
40	11.95	0.584	48.9	7,000
50	13.0	0.584	45.0	7,600
60	14.1	0.628	44.5	8,850
70	15.1	0.648	43.0	9,800
80	16.5	0.663	40.1	10,950
90	17.7	0.712	40.1	12,600
100	19.2	0.765	34.9	14,700

that contact resistance varies almost linearly with the reciprocal of the peak current. Under such circumstances, the rate of heat input to a workpiece is not proportional to the square of the welding current. Indeed, in cases of thin sheets of material of high electrical conductivity, the peak rate of heat input is almost directly proportional to the magnitude of the current, especially in the case of thin sheets of aluminum.

Table 2 shows the resistance and peak values of voltage, current and power input relating to the welds made in 0.025-in. aluminum and 0.064-in. stainless steel, Figs. 33 and 35. For the welds in aluminum, the data refer to the 17th half cycle of current flow and for stainless steel the 13th half cycle.

SUMMARY AND CONCLUSIONS

The results of this exploratory survey of resistance variations during 60-cps. spot welding revealed that:

1. The resistance of a workpiece was not constant during the formation of a weld, and its variation modulates the welding current wave-train to a degree dependent on the electrical characteristics of both the workpiece and the welding machine. Consequently, in the absence of automatic welding current regulation, it is improper to specify a constant welding current when relatively large resistance variations occur in the workpiece.

2. The static resistances of single sheets of the same material and of the same thickness subject to low electrode forces may vary widely from specimen to specimen in the absence of current. However, at high electrode forces, similar specimens of the same material possess more consistent resistance values.

3. When subjected to a single-cycle impulse of current, the resistance of a single sheet of material falls to a value which is almost inversely proportional to the peak value of the current and is independent of the force.

4. The breakdown of contact resistance occurs during the period in which the current is increasing and once the peak current has been attained no appreciable reduction in resistance occurs. During the period of increasing current, the instantaneous resistance appears to be a linear function of the reciprocal of the instantaneous current. As a consequence of this fact, the voltage developed across the workpiece during the period of increasing current tends to remain constant.

5. Contact-resistance breakdown occurs not only during the first half cycle of current flow but also during the second half cycle of conduction. Moreover, the direction of current flow across a contact appears to influence the degree to which contact resistance is broken down.

6. During the formation of a weld in aluminum using cleaned electrode tips, the resistance tended to increase slightly with time after the initial breakdown of contact resistance. For aluminum-contaminated electrodes, however, the resistance tended to decrease with time after contact resistance breakdown.

7. For welds in stainless steel, a continuous decrease in resistance was recorded.

8. The resistance-time curves for welds made in low-carbon steel were found to be more complex, showing an increase and subsequent decrease in resistance after the breakdown of contact resistance.

9. Adjacent welds showed a marked effect on weld resistance.

10. At a given instant during the formation of a weld, the greater the welding current, the lower the resistance. Consequently, if the welding current is varied, the rate of heat input to the workpiece does not change as the square of the current. For sheets of high conductivity material such as aluminum, the peak rate of heat input varies almost linearly with the current.

11. The apparent area of contact of the electrodes on the workpiece has a relatively small effect on its resistance.

12. No direct method for recording instantaneous variations of spot-welding resistance are available.

13. The techniques described in the reported studies are technically satisfactory but are time consuming.

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Safe Practice in Oxyacetylene Welding and Cutting

Safety in welding and cutting has been achieved through recognition of the hazards and through the establishment of proper precautions to deal with them

by Simon A. Greenberg

WELDING *is* safe. According to statistics you are probably safer while welding than while driving your car along a highway on a holiday weekend. That welding is safe is no accident!

Safety in welding and cutting operations has been achieved through the cooperative efforts of management, employees, equipment manufacturers and all others interested in good welding practices. Organizations such as the AMERICAN WELDING SOCIETY and the International Acetylene Assn. provide the means for bringing these different interests together and promoting the general use of good practices.

Safety in welding and cutting has become an accomplished fact through a recognition of the hazards involved in dealing with fire, compressed gases, hot metal, sparks, fumes and other such sources of hazard, and through the establishment of proper precautions to control the hazards involved.

The efforts of A.W.S. and I.A.A. have resulted in the availability of information on safe practices and its adoption by industry. The International Acetylene Assn. has been a leader in this field. Its publication, *Safe Practices for the Installation and Operation of Oxy-Acetylene Welding and Cutting Equipment*, is universally recognized. More recently a new American Standard, *Safety in Electric and Gas Welding and Cutting Operations*, has been issued by the AMERICAN WELDING SOCIETY. This standard replaces the American War Standard of the same name which was so widely used during the last war. The Committee which prepared Z49, as this standard is usually called, included equipment manufacturers, welding engineers, safety engineers, insurance company representatives and governmental labor officials. The requirements are sound and practical, yet provide the necessary protection. Adherence to the practices recommended in Z49 or the I.A.A. *Safe Practices* booklet will assure safety in welding and cutting.

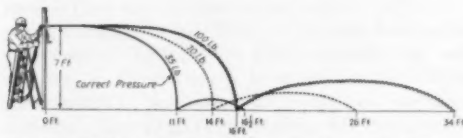

Fig. 1 Relation of cutting-oxygen pressures to distances resulting sparks will fly

A review of the requirements of Z49 will show that *safe* practices in welding and cutting are the same as *efficient* practices for these operations. For example, use of excessive pressures in gas welding or cutting not only may cause flying sparks, but waste fuel gas. Figure 1 shows how excessive oxygen-cutting pressure increases the distance that sparks will fly. Strewn scrap and dirt are a fire hazard; they also hamper movement of the welder or cutter, hence make welding or cutting more difficult. Poor ventilation may not only be a source of toxic fumes, but may make visibility difficult, causing poor welding.

We have already agreed that safe welding depends on cooperation from everyone. Let us now review a typical setup for gas welding and note the part each of us must play in achieving safety. (The same basic factors will apply to oxygen-cutting operations.)

To begin with, management must do its share by providing a safe location, specifically designated for regular welding operations. (This is as true for maintenance welding as it is for production welding.) Regularly designated welding areas should have floors of noncombustible materials, should be well lighted and well ventilated. Proper benches, material handling and positioning equipment should be available to permit safe and efficient handling of assemblies before, during and after welding.

From the standpoint of welding equipment and materials, cylinders, torches, hose and other welding apparatus should all have proper locations and hangers

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Fig. 2 A safe and convenient means for transporting and using cylinders

provided as necessary to prevent damage. Such facilities should include stands, cradles or other means for handling and fastening cylinders during use to prevent their falling. (Figure 2 shows a welding setup with cylinders securely fastened to a hand truck.) The hose is neatly coiled. They should also include a proper location, away from the welding area, for storing cylinders not in use and for storing empty cylinders to be returned to the supplier. Figure 3 illustrates a good storage arrangement for cylinders not in use. Oxygen cylinders are separated from acetylene cylinders, as are full cylinders from empty cylinders. Provision should be made for hanging torches and hose in a safe location when not in use. Proper eye protection should be provided for welders and helpers and the welding area should be divided from the rest of the shop by flame proof curtains or partitions.

Equipment manufacturers and suppliers do their part by providing equipment which has been carefully designed and engineered with safety in mind. Equipment, such as torches, should have the seal of approval of the Underwriters' Laboratory, or the Factory Mutual Laboratories or a similar agency. Hose should be of durable construction and conform to the requirements

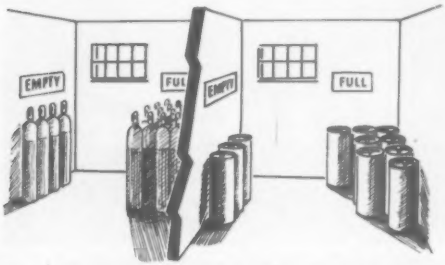

Fig. 3 Proper storage facilities for cylinders not in use

of Z49. Equipment manufacturers go to considerable trouble and effort to furnish information concerning the handling and operation of their equipment. Such information should be available to operating personnel and posted in a conspicuous location in the welding area. The posters and instruction sheets provided with standard equipment should not be put away in a file or safe. They are valuable, but only when available for ready use. No one should be permitted to weld or cut before he can demonstrate that he is thoroughly familiar with the instructions for handling his equipment.

This brings us to the responsibility of the welder. His responsibility for safety is no less than that of management or the equipment manufacturer. He has been provided with safe and efficient equipment and materials and a safe location for welding. Careless or improper use of these facilities on his part will result in an accident in spite of all the good efforts of management. Having established the habit of using safe practices, it is just as easy to follow them as it is to take what may appear to be a short cut. A welder should learn to set up his equipment properly. The instructions of the manufacturer as to the connection of regulators to cylinders and the attachment of the torch should be followed. Not all torches operate alike; this is true not only for torches made by different manufacturers, but for different torches made by the same manufacturer. A match should never be used to light a torch; always use a friction lighter, as shown in Fig. 4. A stationary pilot light is satisfactory for large production operations. Before starting to weld, a check should be made to see if there is any dirt or scrap which should be cleared away. The work should be examined to be sure that it is secure and will not fall during welding, and that it is not oily or greasy.

Fig. 4 Proper use of friction lighter for lighting torch

Proper maintenance of equipment cannot be overstressed. Equipment should be treated with care. Torch tips and nozzles, for example, should be cleaned with the proper size twist drill or a piece of soft brass or copper wire. Figure 5 shows the proper use of a tip cleaner for cleaning a torch tip. An up-and-down motion

Fig. 5 Proper use of tip cleaner on cutting nozzle

is used, not a rotary motion. Worn or damaged equipment should not be used. Replacement should be made with standard parts, properly attached. Makeshift repairs are worse than none at all. Equipment should be checked periodically and tested for leaks. Leaks in torch and regulator valves may sometimes be corrected by merely tightening the fittings; worn parts should be replaced. When in doubt, return the equipment to the supplier for check and replacement if necessary.

Worn and leaking hose and hose connections should be repaired. Defective hose should be cut out and suitable splice made, using proper hose connections, as shown in Fig. 6. Empty cylinders should be marked "Empty" or "MT" and removed from the welding area after all valves have been shut and valve-protection caps replaced.

It is good practice to identify the contents of a cylinder by the name of the gas, which should be clearly shown on the cylinder. The color or shape of a cylinder is not a positive means of identification.

Should there be occasion to stop work for a short period of time, as when changing welding rods or moving the work, both the oxygen and acetylene valves on the torch should be closed. The torch should be hung up or placed where it will not be damaged. When the welding is to be stopped for a considerable length of time, as at noon or when changing shifts, the entire setup should be shut down, including torch and cylinder valves in the proper order as given in manufacturer's instructions.

The welder should be properly attired for his work. Woolen clothing is preferred to cotton clothing, not only because it is not so readily ignited, but because it also protects the welder from changes in temperature. Cotton clothing, if used, should be chemically treated to reduce its flammability. All outer clothing should be clean and free from grease and oil. Since sparks may lodge in rolled-up sleeves or pockets, sleeves should be rolled down to the wrist and kept buttoned; pockets should be eliminated from the fronts of shirts and aprons. Similarly, trouser cuffs provide a trap for sparks; trousers should either be cuffless or turned up on the inside. What the well-dressed welder should wear is pictured in Fig. 7.

Low-cut shoes with unprotected tops should not be used, except for small bench operations. For very heavy operations safety shoes, with hard toes, should be worn. For overhead welding, or welding in very close quarters, ear protection should be provided. Hard hats or head protectors should be worn where there is exposure to sharp or falling objects.

Goggles must be worn during all welding operations, by helpers as well as welders. The types recommended for different operations are carefully described in Z49.

Fig. 6 Use of hose splice to connect two sections of hose

Fig. 7 Proper clothing for gas welding and heavy cutting

All parts of goggles should be substantially constructed and be able to withstand the heat of welding. Naturally, they must be flameproof, and of a material that will not readily corrode or irritate the skin.

The shade of lens depends largely on the individual vision of the welder. It should be dark enough to prevent irritation to the eyes due to glare, yet light enough so that the welder can see what he is doing. A guide to the proper shade of lens to use for different operations will be found in Z49. Shade No. 5 is recommended for light oxygen cutting and gas welding. Shade No. 6 is recommended for oxygen cutting and for medium gas welding, and Shade No. 8 is recommended for heavy gas welding. All lenses, regardless of shade, should be optically correct and should be kept clean. They should be replaced when visibility is impaired by slag, scratches or cracks. It is poor practice to transfer goggles from one employee to another without first sterilizing them; this is just a good health measure.

All of the foregoing precautions and safety measures can easily be practiced in regular welding areas. However, when welding has to be done at other sites, as in making a repair, or as in field welding, these ideal conditions are not always possible and additional special precautions become necessary.

If repair welding has to be done in a shop, for example, the floor should be swept clean and all combustible material removed. Wooden floors should be thoroughly wetted down with water, or covered with damp sand, sheet metal, asbestos or some other similar material. Where there are floor openings or cracks that cannot be closed or covered, the area on the floor below, directly beneath where welding is to be done, should be checked to make sure that there are no highly combustible materials which may be ignited from welding sparks. Combustible material which cannot be moved should be completely covered with tarpaulin or asbestos sheets, as shown in Fig. 8. The welding equipment should be so located that it will not be exposed to damage. Hose should be neatly stacked and not left

Fig. 8 Use of sheet-metal guards and asbestos sheets to protect combustible materials

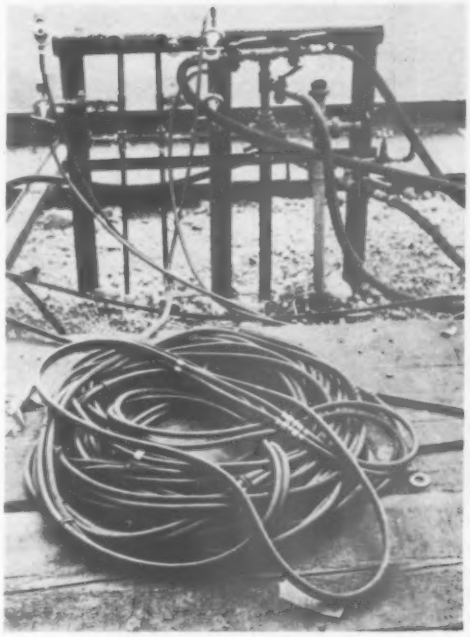

Fig. 9 A properly stacked coil of hose

where it will encumber the welding operations, or where it can be struck by falling metal or run over by hand trucks, carts or stepped on. Neatly stacked hose, as shown in Fig. 9, not only protects the hose from damage, but makes it easier to draw additional lengths of hose as required.

Welding can be done safely in confined spaces, as in tanks or the holds of ships. In such cases it is mandatory that proper ventilation be provided either to completely ventilate the space, or by providing individual respiratory equipment to each welder. This is necessary even where there is no likelihood of the accumulation of toxic fumes, in order to prevent oxygen deficiency.

The gas cylinders should be left on the outside of the confined space, and, where possible, an attendant stationed on the outside to shut off the gas supply in an emergency.

When the welder must enter such confined spaces through a manhole or other small opening, some means must be provided for quickly removing him in case of emergency. Safety belts or life lines are convenient means for such purposes.

When it is necessary to stop work, the welder should not leave the confined space without shutting off his equipment at a point outside the confined area. He should preferably remove his torch, although this is not mandatory if the work is to be resumed shortly.

When welding is to be done on platforms, scaffolds or runways at above-ground elevations, the welder should

Fig. 10 Fire-extinguishing equipment

be protected from falling by means of railings, safety belts, life lines or similar means.

In all the above cases fire-extinguishing equipment should be provided as necessary. Such equipment should include at least one fire extinguisher, properly filled, fire hose and buckets, as sketched in Fig. 10. In some cases it may be desirable to provide fire watchers. If so, such fire watchers should be retained at the welding location for a sufficient length of time after the welding is completed to assure that no fire hazard exists. In any case, the welder, upon completion of his work, should mark his work or otherwise indicate that it is hot, to warn other workers, as shown in Fig. 11.

Drums, barrels, tanks and other containers that have held combustible gases or liquids should be completely cleaned and purged before any welding or cutting operations. Pipe lines should be disconnected or blanked to prevent the flow of any gas or liquid through the area to be welded or cut. All hollow cavities and containers should be vented to permit the escape of air or gases.

If it is possible, the previous contents of the container should be determined. This is not always possible, and in such cases all precautions should be taken. All containers, whether they contained grease, oil, gas, acid,

Fig. 11 Welder marking work to warn other workers

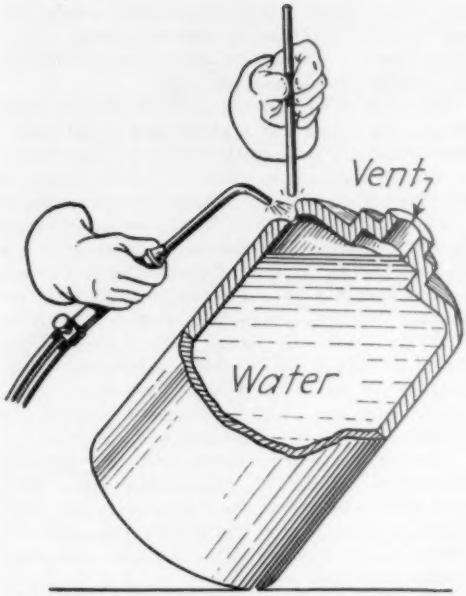

Fig. 12 Welding container which has held combustibles

tar or any other similar substance, should be thoroughly cleaned. For very volatile substances steam or very hot water may be used. For other substances, such as heavy oils, a strong solution of caustic soda may be used. For other substances it is necessary to use a solvent.

Even though the container has been cleaned, the welding or cutting operation should be further safeguarded by filling the container with water, as shown in Fig. 12, to within a few inches of the point of welding or cutting. If filling with water is not practical an inert gas may be used. Carbon dioxide and nitrogen are commonly used. *Carbon monoxide or the exhaust from an automobile engine should never be used.*

Where a gas is used for purging it is necessary to make sure that the proper concentration of gas is maintained. The carbon dioxide concentration should be at least 50% in the air space inside the container, and 80% or more in the presence of hydrogen or carbon monoxide. The required concentrations for nitrogen are at least 10% higher than those for carbon dioxide. A typical setup for using carbon dioxide or nitrogen is illustrated in Fig. 13. The subject of welding and cutting such containers is covered in greater detail in the A.W.S publication, *Recommended Procedure to Be Followed in Preparing for Welding or Cutting Certain Types of Containers Which Have Held Combustibles.*

The one other subject which should be mentioned briefly is the welding of materials which, when heated, give off toxic fumes. It should be noted that except when welding certain metals, such as lead and zinc and materials coated with these metals or cadmium, or mercury-bearing substances, there is no hazard of toxicity. When

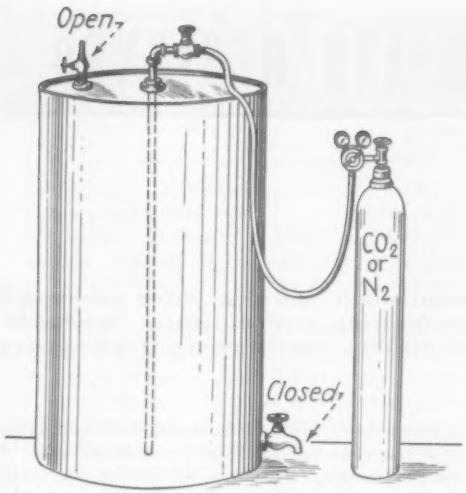

Fig. 13 Purging tank with carbon dioxide or nitrogen for welding or cutting

Fig. 14 Proper hood for drawing off fumes

welding the metals mentioned above, or other metals coated with these metals, local exhaust ventilation, by means of hoods as shown in Fig. 14, or ducts located directly at the welding station and as near as practicable to the work, must be used to provide the air changes prescribed in Z49. Individual air-supplied respirators may be provided as an alternative. If welding of such metals is done infrequently it may be most convenient to perform the welding outdoors, in which case special ventilation or respiratory equipment may not be necessary.

Welding fluxes in general are not toxic; an exception is fluoride-bearing fluxes. Such fluxes are more commonly used for brazing than for gas welding. In addition to the need for removing all toxic fumes generated by such fluxes by means of positive ventilation, precautions must be taken to prevent quantities of the flux itself from being taken internally. Observance of usual cleanliness requirements, such as washing the hands before eating, will eliminate all possible hazards from this source. The AMERICAN WELDING SOCIETY has formulated a standard precautionary wording for inclusion on the labels of fluoride-bearing fluxes, which has generally been adopted by flux manufacturers. A careful reading of these instructions as well as the literature of flux manufacturers on the same subject is strongly urged.

It is difficult to cover every detail of safe practices in so short a space. Only the high lights have been covered, and it is suggested that the safety standards mentioned be reviewed in detail.

The important thing to remember is that the responsibility for safe welding and cutting practices is that of *everyone*—employer or employee. So, too, the benefits from safe welding and cutting are everyone's: neither loss of property, injuries, lost time or earnings, nor loss in production time.

With everyone doing his part we will only have unavoidable accidents—which do not exist.

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PRACTICAL WELDER AND DESIGNER

Good Welding Setups

Automatic and semiautomatic machines using submerged arcs do fast work besides insuring excellent joints. Some weldments displace cast steel, yielding superior products at lower cost

by James E. Dipert

EFFORTS to obtain maximum advantage from arc welding of many components for several different types of products have led Gar Wood Industries, Inc., to install excellent setups for such work in this company's Findlay, Ohio, plant. Some of the automatic and semiautomatic equipment being used to good purpose is here illustrated. Many straight submerged arc welds are produced in machines, like that in Fig. 1, that include fully automatic Lincolnweld equipment.

In these machines, the automatic head is supported on a horizontal track 16 ft. long that is quickly adjustable for any height within a 6-ft. range by motors that drive elevating screws by chain. This track is supported from transverse beams that also permit of quick front-to-back adjustment up to a total of 6 ft.

In general, the workpiece is clamped to or supported on trunnions so that it can be turned easily to bring the piece into most convenient position below the head. A trunnioned support is shown in the close-up, Fig. 2, and has jaws between which the workpiece is fastened by bolts that pass through tapped holes in the jaws. Trunnions rest on wheeled dollies, Fig. 1, that are easily moved to support a workpiece of any length within the limits of the machine.

Next to each of these machines is a jib crane equipped with an electric hoist and tongs that can pick up the workpiece and place it quickly between trunnion jaws, if used, or on other supports if they are more convenient, and remove the workpiece when welds are completed.

In the case of box-section assemblies, like that for the truck crane outriggers shown in welding position in Figs. 1 and 2, the workpiece is first tack welded else-

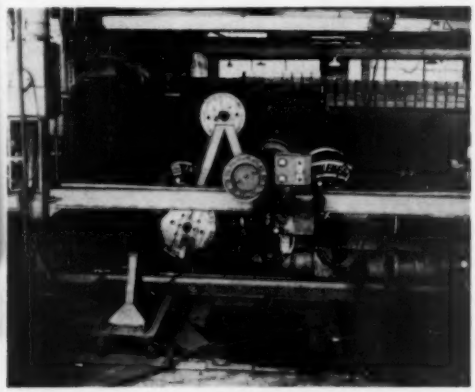

Fig. 1 One of the large setups installed by Gar Wood Industries, Inc., for making straight automatic Lincolnwelds on long parts, one of which is shown supported on trunnioned dollies below the welding head

Fig. 2 Close-up of a portion of the setup, Fig. 1, showing a truck crane outrigger clamped in a trunnioned jaw. The operator is using a suction nozzle to draw off excess flux back of the weld

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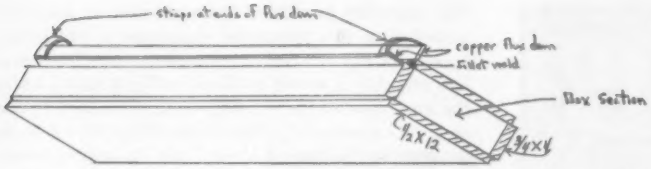

Fig. 3 Sketch showing a cutaway portion of a box-section outrigger made from $^{3}/_{4}$- and $^{1}/_{2}$-in. steel plates, tack welded before making automatic fillet welds. The copper frame forms a trough to hold the granular welding flux

where and then is shifted to the automatic welder for making the longitudinal welds. In such instances, the plates that form the box are tacked so that their inner faces form a box and leave at each corner a 90-degree space between the edges of the plates, as in the sketch, Fig. 3.

With this arrangement, if the box section is held with its faces at 45 degrees with the horizontal, the plate edges form a trough in which a fillet weld is rapidly and conveniently made. Copper strips held 90 degrees apart by a frame are set over this trough and help to hold the flux as it feeds out from the automatic head. This frame is about 3 ft. long and is slid along the workpiece as needed. When thus set up, welds can be made at a speed of 24 in. a minute, using $^{7}/_{32}$-in. wire and 600-amp. current.

As the head functions automatically, the operator follows along with a suction nozzle that draws off the excess flux and returns it to the container (top left in Fig. 1) for re-use. When the first fillet weld is completed, the workpiece is shifted 90 degrees for the next longitudinal weld. Others are then completed in succession until all four are done. Short welds along the ends of the outrigger are then made by ordinary hand welding, using coated rod, or by hand-held semiautomatic "squirt" welding, as these welds are too short to warrant setups under the fully automatic machines.

In this plant, considerable welding formerly done by conventional hand welding is now being handled by Lincoln semiautomatic squirt welders because time, in such cases, is commonly reduced by about one-third and excellent welds result. Although the generators supplied for these squirt welders are capable of 600-amp. output, they are commonly used with about 350 amp. As this is applied to $^{5}/_{64}$-in. wire, however, very fast melt-off rates, high-current densities, and excellent penetration result in first-class welds.

Semiautomatic squirt welding is now being applied for many jobs and with much success in fabricating a variety of weldments. Several such are employed in an assembly known as a double-drum cable control unit employed on tractors for the control of earth-moving scrapers and the like. Until recently, the components in question were steel castings but so many of these castings contained blow holes or other defects that they

Fig. 4 Using a Lincoln semiautomatic squirt welder to produce a circular fillet weld for joining a hub ring to a dished stamping that forms half of the spool for a cable drum

Fig. 5 Making the squirt weld that fastens the two halves of a cable drum spool together, as the work is rotated slowly by a positioner whose table is set in a vertical plane

Fig. 6 Squirt welding a second hub ring into a drum spool produced from wrought steel components. This assembly is lighter and costs less, yet is superior to the cast steel drum that it replaces

have now been superseded by weldments, which cost less, require less machine work and constitute a better product, besides avoiding dependence upon foundries that are overloaded.

Among the parts for these cable-control units now being squirt welded are cable drums. Welding being done on these is shown in process in Figs. 4, 5 and 6. The spool-like portion of this weldment is made up largely from two hot-dished stampings of which one appears in Fig. 4. Each of these stampings receives a hub ring that is welded in place, as Fig. 4 shows, while the workpiece is rotated slowly under the squirt welder on a work positioner. This circular hub weld is 8 in. in diameter and is made in about 3 min. as against 4 min. for hand welding.

Halves of the drum spool are tack welded together before the second hub ring is applied. After tacking, holes are flame cut to fit a stamped fitting that later fastens the end of the cable to be wound on the drum. This fitting is hand arc welded to the edge of the hole and is flush with the inner spool surface.

Subsequently, the halves of the spool are squirt welded to join the two, as shown in Fig. 5. This weld is made with the positioner table swung into a vertical plane. Speed of rotation on most of the welds made in the positioner is not constant but is varied by a pedal control to suit whatever gap there may be at the joint.

After the two spool halves are welded together, the positioner is again shifted so its table is horizontal and the second hub ring welding is completed, as in Fig. 6. Finally, the workpiece is turned over and a large ring, previously tack welded to one flange, is squirt welded to the flange. By using the squirt welder as noted, total welding time is now about 1 hr. as against about $1^1/_2$ hr. when all hand welding was done.

Some portions of the weldment require machining after welding is completed but, as a rule, no more than $^1/_{16}$ in. of metal need be removed, as against about $^3/_{16}$ in. minimum for cast-steel drums. Weldments weigh about 28 lb. less than castings, cost at least 10% less and are a superior product.

Giant Size Hex Nuts Flame-Cut with Ease from 24-in. Billets

GIANT size hex nuts for a 250-ton hydraulic press are cut to shape by the oxyacetylene cutting process at General-American Transportation Co., Sharon, Pa. The Oxweld C-37-R cutting blowpipe mounted on an Oxweld CM-23 cutting machine easily slices through the 24-in. thick, low-carbon steel billet. Cutting is accomplished at the rate of 3 in. per minute. A hole was first cut out of the center of the block whose sides are then cut in the shape of a hexagon. After they are cut to shape, the hex nuts are threaded for column bolts in a hydraulic press. No other machining is necessary to complete these parts.

Cadmium Fume Hazard

CADMIUM is now recognized as an excellent plating material in many industrial applications. Its wide use requires that we be constantly alert to the hazard in welding or cutting cadmium-bearing materials. No opportunity should be lost to educate those who may at any time conceivably be exposed to cadmium fumes. Foremen and safety supervisors should also be made aware of the hazards of working with cadmium-bearing materials.

The August 1951 issue of the Wisconsin State Board of Health's *Industrial Health Monthly* carried an article on the subject by Walter H. Poppe, Jr., and engineer with the Board's Industrial Hygiene Division. Mr. Poppe's story, "Cadmium the Killer," is timely and to the point and is reprinted here in full.

"In Wisconsin since the first of this year, there have been two industrial deaths attributed to the inhalation of cadmium fumes. This is a very alarming fact when one considers that medical literature reports only 60 such cadmium poisoning cases from the years 1858 to 1945 and that only 10 of these cases resulted in fatalities.[1, 2]

"Cadmium is widely used for electroplating other metals. It produces a silver-white coating that takes a high polish and protects the base metal from corrosion. Plating with cadmium does not create any more of a health hazard than plating with many other commonly used metals. The trouble starts when heat is applied to metallic cadmium or its salts, either with a welding torch or by some other means. The two deaths which occurred in Wisconsin this year will illustrate this point.

"In the first case, a cadmium-plating tank was being changed over for use as a zinc tank. There was a coating of cadmium, probably cadmium salts, on the lining of the tank which did not yield easily to scraping or chipping. An employee resorted to the use of an acetylene torch and his death resulted.

"In the second case, an employee was engaged in spot welding cadmium-plated steel. He died in a hospital 6 days after his exposure to the fumes, which resulted from this application of heat to cadmium.

"If the extremely toxic nature of cadmium fumes had been appreciated and proper local exhaust ventilation or approved type respirators had been used in conformance with the General Orders on Dusts, Fumes and Gases issued by the Industrial Commission, these men would not have died.

"Cadmium-plated metals can be confused easily with electroplated zinc-coated metals; but, unlike zinc, the oxide of cadmium formed when the metal is heated in air is brown, while the similar oxide of zinc is white. Thus, cadmium provides its own mark of identification.

"Should there be any doubt in anyone's mind whether a metal is cadmium- or zinc-plated, a sample of the metal in question should be submitted to a competent chemical laboratory for analysis. Welding should never be performed on a metal or plated metal of an unknown identity.

"There are spot checks that can help to determine whether or not a piece of metal is cadmium- or zinc-coated. A cadmium-plated object will form a yellow-gold film when heated gently with a welding torch, whereas a zinc-coated object will turn smoky dark gray. Another method is to apply a drop of concentrated hydrochloric acid on the metal surface; then allow a few seconds for the acid to dissolve the coating. To the spot where acid was applied, add a drop of ammonium hydroxide which has been saturated with hydrogen sulfide. A bright yellow precipitate will indicate the coating is cadmium, while a white precipitate will indicate a zinc coating.

"Feigl suggests the use of diphenylcarbazide.[3] An alcohol solution of the material buffered with a saturated aqueous sodium acetate solution will form a red-violet precipitate in the presence of cadmium, while no precipitate is formed in the presence of zinc.

"It is recommended that these spot tests be used on known pieces of cadmium- and zinc-plated materials so that the user will become familiar with the result and be able to distinguish the difference between these two metals. Do not take it for granted that box labels are correct. Boxes labeled cadmium-plated may contain zinc-plated objects, and the same may be true of boxes labeled zinc-plated.

"The maximum allowable concentration for chronic or prolonged exposure to cadmium has been set at 0.1 milligram per cubic meter of air. While there is some disagreement on this limit between authorities in the field of toxicology, there can be no mistake about the effects of acute exposure to high concentrations of the fumes of this metal. They are often fatal."

How to guard against cadmium poisoning is covered in our "Safe Practices" pamphlet and in American Standard Z49.1-1950, "Safety in Electric and Gas Welding and Cutting Operations." Rule 8.2.1 of Z49.1-1950 is:

"All welders engaged in welding or cutting metal coated with lead-, cadmium-, or mercury-bearing substances or containing lead or cadmium shall be pro-

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vided with an approved type air-line respirator or hose mask except where local exhaust ventilation, as per Rule 8.5, sufficient to control the fumes generated is provided and used. Exhaust ventilation shall not be substituted for required respiratory protection in welding or cutting operations inside confined spaces."

References

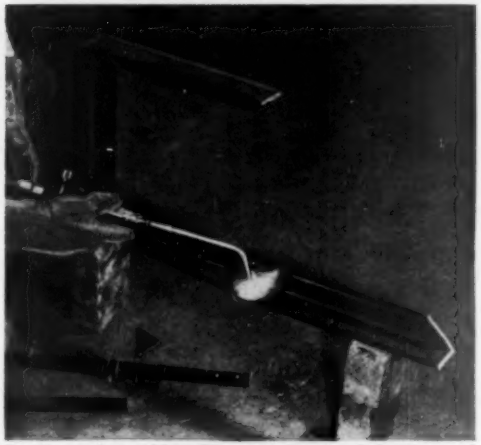
1. Spolyar, Keppler and Porter, "Cadmium Poisoning in Industry; Report of Five Cases, Including One Death," *Jln. Ind. Hyg. & Tox.*, **26**, 232 (1944).
2. Huck, Frank F., M.d., "Cadmium Poisoning by Inhalation," *Occupational Medicine*, **3**, 141 (1947).
3. Feigl, F., *Spot Tests*, Nordemann Publishing Co., Inc., New York 47 (1939).

Practical Heating Tricks

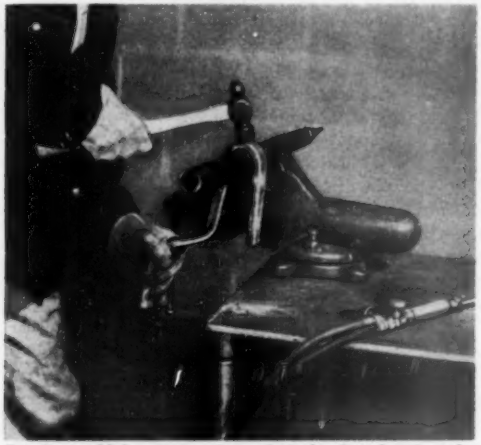
by F. C. Geibig

THE oxyacetylene blowpipe is the handiest tool in the shop for heating steel for bending, straightening and shaping. Almost any spot can be heated quickly. And by moving the flame away from the work or closer to it, heat can be controlled easily and accurately. The photographs show just a few of the many jobs which can be done by heating with the blowpipe.

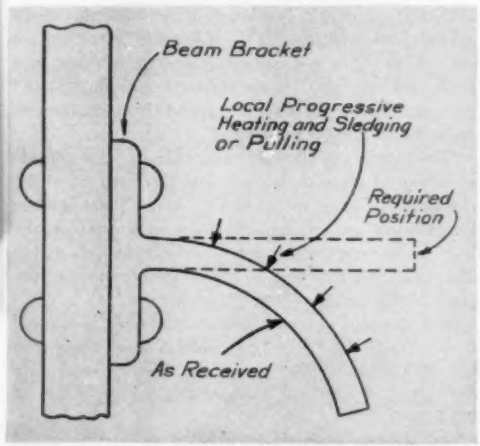
F. C. Geibig is connected with Linde Air Products Co., a division of Union Carbide and Carbon Corp., Newark, N. J.



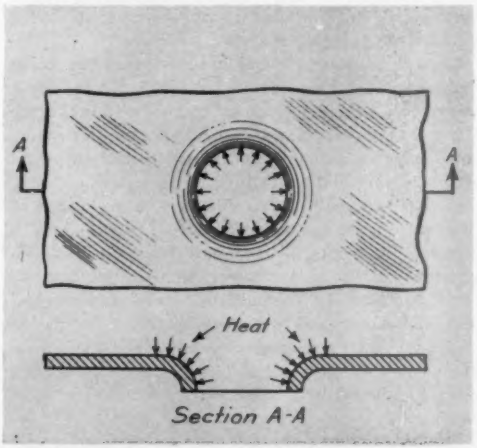
***Bending:** A portable welding tray is a simple heating and bending job. First cut notches in one flange of a piece of angle iron. Then heat other flange to a red heat and bend*



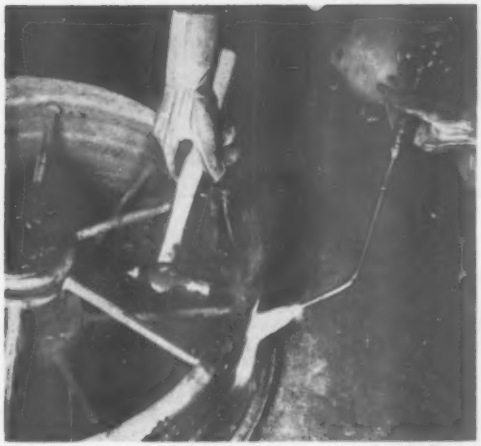
***Bending:** Make a strap iron clevis by first heating the metal to a red heat, and then bending it around pipe when it cools slightly. Use a neutral flame for heating jobs*



***Straightening:** Bracket arms that have been bent in service are easily straightened by heating as shown here, and then applying a pulling force until the arm is straight again*

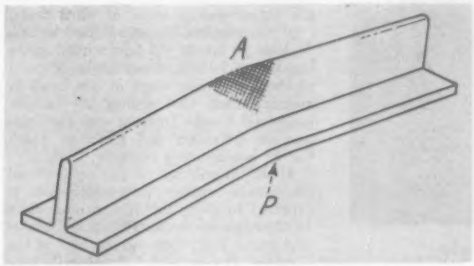


***Forming:** Flanges are easily formed by heating the area shown and then forging it to the shape required. Move the blowpipe in circles to heat evenly*

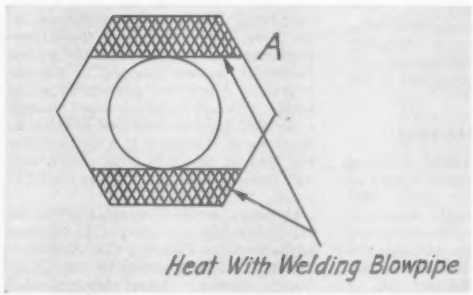


Straightening: This binder wheel was split and bent. To do a job like this, heat the twisted part of the rim. When the metal under the flame turns dull red, use a hammer to reshape it

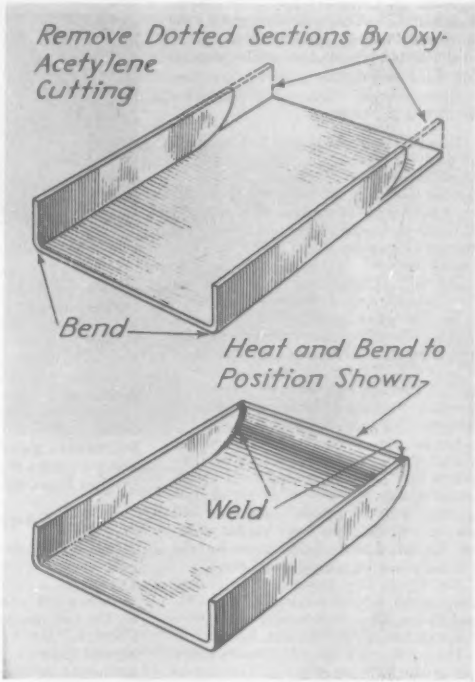
Loosening: Heat a rusted fitting until it turns a dark red. Then it will be easy to turn off with a wrench. Keep the heat on the nut and away from the bolt



Straightening: Parts like this that have been bent out of shape by a blow at P are easily pulled back in line by heating at A. Heat another triangular patch next to the first, if the part doesn't fully regain its shape after cooling



Loosening: Nine out of ten rusted nuts will come off if you heat the shaded areas as shown here



Forming: Use your cutting and welding blowpipes to form a shape like this from a piece of sheet steel

the AMERICAN WELDING SOCIETY

activities • related events

Membership Directory

The 1951 Membership Directory containing alphabetical and geographical listing of Society members is available without charge to members of the SOCIETY upon request to headquarters.

Adams Lecturer

JOHN J. CHYLE

John J. Chyle, Director of Welding Research, delivered the 1951 Adams Lecture. His subject was "Welding of Copper by the Inert Gas Metal Arc Process." Mr. Chyle described the welding procedure which was developed for shop application and gave an illustrated presentation of the properties of the weld metal.

Biography of Author

John J. Chyle graduated in Chemical Engineering from the University of Wisconsin in 1924.

After working for one year at Smith Steel Foundry, Milwaukee, he joined the A. O. Smith Corp. as a chemist in the Production Laboratory. In 1926 he was named head of Welding Electrode Research at A. O. Smith, and in 1936 he was appointed Director of Welding Research.

Mr. Chyle has invented and patented a number of welding electrodes and welding processes. The first extruded, all-position type of electrode was developed by him in 1927. This original electrode was of the cellulosic titanium dioxide type, which is now classified as the E6010 type.

Special alloy electrodes for the welding of high-strength alloy steels were also developed by Mr. Chyle, and used extensively during World War II on aircraft landing gears, torpedo airflasks and bombs. Welding processes originated under his direction included those for the welding of low-alloy high-tensile steels.

Mr. Chyle also directed the development of the welding procedure for the 11- and 22-ton demolition bombs which were developed during the last war.

During the war Mr. Chyle was a member of the Subcommittee on Welding of Armor. He also participated in the work essential to the production of the atomic bomb, which was part of the Manhattan District Project.

Mr. Chyle is active in technical committees and in technical societies, including THE AMERICAN WELDING SOCIETY, American Society for Metals, America Society for Testing Metals and the American Society of Mechanical Engineers. He has held the office of Chairman of the Milwaukee Section of THE AMERICAN WELDING SOCIETY and is a member of the Board of Directors of the SOCIETY.

John J. Chyle

Mr. Chyle is Chairman of the Automotive Committee, and a member of the Technical Activities Committee of THE AMERICAN WELDING SOCIETY.

He has also served on many other committees of THE AMERICAN WELDING SOCIETY and assisted in the preparation of many chapters of the 1950 edition of the *Welding Handbook*.

32nd Annual Meeting

One of the most successful meetings held by the SOCIETY came to a close in Detroit on October 19th. About 1600 members and guests officially registered for the technical and other sessions of the SOCIETY. About 500 people attended the Annual Dinner of the SOCIETY. Over 500 attended the special inspection trip to the Ford Motor Plant. About 400 attended the President's Reception on Monday evening October 13th. All of the technical sessions were well attended. Members and guests found occasion to attend the National Metals Exposition from two to several times. An unusual feature was the World Metallurgical Congress. Some 35 foreign delegates from all over the world attended the welding group meeting.

Centennial of Engineering

With figures like Herbert Hoover, Charles F. Kettering of General Motors, and B. F. Fairless, president of U. S. Steel, prominent on its directorate, the Centennial of Engineering to be held in Chicago in 1952 has reached a stage of development indicating that it will be one of the most important demonstrations of technical progress ever staged.

In announcing a full-scale launching of plans for the celebration which will extend from July 1st to September 30th next year, Lenox R. Lohr, Centennial president, reported that it already has the active participation of 41 national and international engineering bodies. At least 30 others will hold special meetings or send token delegations. Typical of the world-wide scope of the event is announcement that among its participants will be the International Commission on Irrigation and Drainage which has its headquarters in Delhi, India.

Actual attendance at the professional conferences during the celebration is expected to bring to Chicago more than 50,000 engineers, industrialists and others in kindred fields from all sections of the Western Hemisphere. There will also be sizable groups from the leading European nations.

Lohr stated that, unlike events sponsored by engineering bodies in the past where the programs have been generally restricted to highly technical matters, the 1952 celebration will have a twin character. While plans call for one of the most diverse series of technical sessions ever staged at one place, the general public for the first time will be brought prominently into the project on a big scale. This will be accomplished through a historic pageant expected to play to hundreds of thousands in a summer-long run, and an especially built exhibit that will continue on display for at least five years.

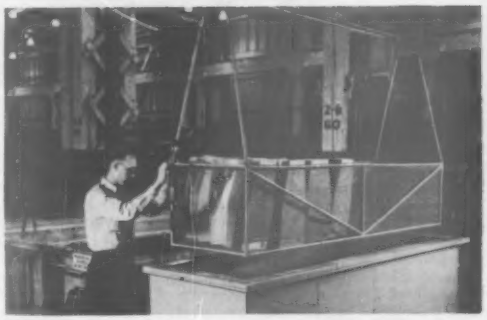
Occasion for the Centennial will be the one-hundredth anniversary of the founding of the American Society of Civil Engineers, oldest engineering society in the United States. However, instead of being limited to this one group, it has been seized upon by practically all other branches of engineering as an ideal occasion to pool their forces in depicting the history and achievements of engineering in all its phases through an integrated program in which each will have its part.

"In planning the Centennial we hope to make it a means of awakening the public to all that engineering has meant not only in industry but in every other

INDEX TO ADVERTISERS

Acetogen Fabricators, Inc. 1043
Air Reduction ..... Outside back cover
American Chain and Cable Co. 1050
Ampco Metal, Inc. 1038
Bastian-Blessing Co. 1064
Becker Brothers Carbon Co. 1046
The Champion Rivet Company 1058
The Diversey Corp. 1033
Dockson Corporation 1042
Eutectic Welding Alloys Corporation 1040
General Electric 1055
Haynes Stellite Company, a Division of Union Carbide and Carbon Corporation 1051
Hobart Brothers Company 971
The International Nickel Company, Inc. 1053
Jackson Products ..... Inside back cover
The Lincoln Electric Company 1049
Linde Air Products Company, a Division of Union Carbide and Carbon Corporation ... 974
P. R. Mallory & Co., Inc. 973
The McKay Company 1035
Metal & Thermit Corporation 972
National Carbide Company 1039
National Foundation for Infantile Paralysis 1034
National Tuberculosis Association 1045
Page Steel and Wire Division 1050
Philip Roden Co. 1059
Square D Company 1047
Stulz-Sickles Co. 1034
Tempil® Corporation 1036
Tweco Products Company ..... Inside front cover
United States Testing Company Inc. 1054
Union Carbide and Carbon Corporation
Linde Air Products Company 974
Haynes Stellite Company 1051
Victor Equipment Company 976
Wagner Manufacturing Co. 1040
Waterman Products Co., Inc. 1038
Westinghouse Electric Corporation 1046
J. H. Williams & Co. 1042
Worthington Pump and Machinery Corporation 1037

Pre-Welding Treatment For Aluminum Increases Spot Weld Output 50%



Naturally, the best surface preparation plus the best welding technique will produce the best spot welds. And, today, many aluminum fabricators are combining their excellent welding techniques with the Diversey Pre-Welding Treatment. Results are outstanding.

Users report improved quality of the welds, increased quantity of spot welds before tip cleaning is required and prolonged life of electrode tips. One user reported an increase of spot weld output of 50%. Another reported an increase of 4,000% in the number of spot welds made before electrode tips required redressing.

The Diversey Pre-Welding Treatment for aluminum incorporates the use of Diversey No. 36 to remove identification markings, grease, dirt, etc.; and the use of Diversey No. 514 to remove oxide, heat scale, and to produce minimum surface resistance. The Diversey Pre-Welding Treatment is easy, efficient, practical, and surprisingly economical to use. Complete information is available. Direct inquiries on your company letterhead to: The Diversey Corporation, Metal Industries Department, 1820 Roscoe Street, Chicago 13, Illinois. In Canada: The Diversey Corp. (Canada) Ltd., Lakeshore Road, Port Credit, Ontario.

sphere of physical progress over the past century," Lohr explained.

"The engineering profession, combined with industrial and business enterprise, creates and distributes quality products at costs the common man can afford to pay. The engineer has been the genius behind mass production, mass distribution, low prices, practically everything that has made possible the spectacular rise in human comforts and living conditions to the degree we now enjoy. Not by luck, not by command, but by the voluntary application of sound scientific, economic and social principles, this has been attained with our natural resources."

Greatest concentration of the various engineering organizations at the Centennial will be during the convocation period from September 3rd to 13th next summer.

Those which will hold individual meetings or participate in the general symposium events in that period include the following: American Concrete Institute; American Society of Civil Engineers; American Institute of Mining and Metallurgical Engineers; American Society of Mechanical Engineers; American Institute of Electrical Engineers; American Institute of Chemical Engineers; American Society of Agricultural Engineers; American Iron and Steel Institute; American Standards Association; American Rocket Society; AMERICAN WELDING SOCIETY; American Meteorological Society; American Foundrymen's Association; American Society of Tool Engineers; American Society for Engineering Education; American Institute of Consulting Engineers; American Society for Testing Materials; American Association of Engineers; American Railway Engineering Association; American Society of Safety Engineers; Boston Society of Civil Engineers; Edison Electric Institute; Engineers Council for Professional Development; Engineering Institute of Canada; Franklin Institute; Industrial Management Society; Institute of Traffic Engineers; International Association for Hydraulic Research; International Commission on Irrigation and Drainage; International Commission on Large Dams; National Conference on Industrial Hydraulics; National Society of Professional Engineers; Society for the Advancement of Management; Society of American Military Engineers; Society of Naval Architects and Marine Engineers; Society of Automotive Engineers; U. S. Council—International Association for Bridge & Structural Engineering; Western Society of Engineers; World Power Conference; and Chicago Section of the American Chemical Society.

While seemingly technical, all of the above meetings will be presented in terms that can be readily grasped by the average layman. Principal purpose, according to Lohr, is to enhance the evaluation of the contributions of engineering to the advancement of civilization on a world-wide pattern—past, present and future. Each subject will be developed with appreciation of its social and economic aspects and of its dramatic appeal.

The pageant, which comprises the second facet in the Centennial program, will be presented at the 1000-seat theater at the Museum of Science and Industry.

It will have a cast of at least 150 actors. Scenes will depict those engineering episodes that have stood out most preeminently for their benefits to human progress. They will be chosen on the basis of their dramatic appeal from among the more than one hundred such events now under consideration. These include such epochal occurrences as the perfection in ancient times of the first wheel, the Roman building of the Appian Way, and others right down to the progress now being made in the harnessing of the atom for peacetime purposes.

All through the pageant's narration will flow the dramatic history of what engineering has done in the constant building toward a better world.

The permanent exposition, third feature in the Centennial planning, will also be presented at the Museum of Science and Industry. It will be open to the public free of charge the year round. Original inventions, models and dioramas will be utilized to show the evolution of engineering. Several of its exhibits will show how dozens of widely varied talents and their products must be brought together to make possible one complete complex machine.

The immensity of the Centennial's program and the big attendance it will attract will require the use of the facilities of practically all Chicago's leading hotels.

Financing of the project is already well under way. Sizable contributions have been received from many of the country's leading industrial companies. The final budget may reach $1,000,000.

Early announcement will be made of other special features under consideration to give the Centennial added general interest. Two already being advanced would provide for a commemorative postage stamp and a commemorative coin. A nation wide publicity campaign will also be conducted.

Headquarters of the Centennial have been established at the Museum of Science and Industry in Chicago where a rapidly growing executive staff is now in action. The Centennial, as such, has been formally chartered as a nonprofit corporation.

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Board of Directors Meeting Minutes

The fifth meeting of the Board of Directors of the AMERICAN WELDING SOCIETY for the 1950-51 year was held on Tuesday, Aug. 28, 1951, at 10:00 A.M., in Parlor E, 4th floor, of the Hotel New Yorker, New York, N. Y., with the following in attendance:

Members: H. W. Pierce, *Chairman*, C. H. Jennings, F. L. Plummer, R. S. Donald, C. A. Adams, L. C. Bibber, T. J. Crawford, O. B. J. Fraser, La Motte Grover, H. O. Hill, A. J. Moses, L. C. Stiles, J. R. Stitt, and C. B. Voldrich.

Staff: J. G. Magrath, *Secretary*, and F. J. Mooney, *Assistant Secretary*.

Auditor: D. Joseph.

Guests: C. D. Evans, Chairman, Technical Activities Committee; I. Morrison, Chairman, Membership Committee; A. G. Oehler, Chairman, THE WELDING JOURNAL Committee; G. O. Hoglund, Chairman, Special Committee to Determine Scope, Purposes and Requirements of Annual Meeting, G. Van Alstyne, Member, Special Committee to Determine Scope, Purposes and Requirements of Annual Meeting; R. W. Clark, Chairman, Standard Qualification Procedure Committee; H. J. Stetina, Chairman, Building Code Committee.

Membership

Mr. I. Morrison, Chairman of the National Membership Committee, acknowledged the excellent work done by the previous Chairman, H. C. Neitzel. He stated that his plans were being rapidly developed for the coming year. They consist of appointment of the right type of organization, which is now in process, laying strong stress upon the reinstatement of delinquent members, more effective work by the Section Membership Committee Chairmen, strong promotion on Sustaining Membership, a personal tour of many of the Sections, a request for more WELDING JOURNAL promotion on membership and active help from the District Vice-Presidents who are, on the basis of the by-laws, members of the National Membership Committee. Chairman Pierce took this opportunity to advise the Board that Mr. Morrison "practiced what he preached" in that he had just applied for Sustaining Membership for his company on the basis of his being the Sustaining Member.

Welder Certification

After considerable discussion a proposal was tendered by Chairman Pierce that a Special Committee on Welder Certification be appointed. It was suggested by the Chairman that this Committee consist of F. L. Plummer, *Chairman*, S. A. Greenberg, *Secretary*, La Motte Grover, Member of the Board, H. F. Reinhard of Public Relations, C. D. Evans of T.A.C., H. J. Stetina of Building Code Committee, R. W. Clark of Standard Qualification Procedure Committee and R. S. Green of the Educational Committee. The Chairman suggested that he and the Secretary develop the scope of activity for this Committee and he advised that the Committee should be given power to enlarge its membership by additional persons chosen from industry and organizations interested in the problem of welder and welder inspector certification and/or qualification.

The Chairman was authorized to appoint the foregoing Committee and the President and Secretary to prepare the scope of activity.

Annual Meeting

G. O. Hoglund, Chairman, Special Committee to Determine Scope, Purposes and Requirements of A.W.S. Annual Meeting, supported by G. Van Alstyne, member of the same Committee, presented their report. At the conclusion of Messrs. Hoglund and Van Alstyne's oral presentation of the reasons and foundation for their report, discussion was held. In the discussion, A. G. Oehler, Chairman of THE WELDING JOURNAL Committee, observed that he did not believe his Committee would have any objections whatever to the program proposed by Mr. Hoglund's Committee.

It was recommended that the Special Committee to Determine Scope, Purposes and Requirements of A.W.S. Annual Meeting be continued, or that some similar committee be appointed, for the purpose of studying over a longer period and in more detail, the multitude of problems involved in the effective organization of the SOCIETY'S Annual Meeting, and for making suitable recommendations; and that this Committee be permitted to suggest additional members, for confirmation of appointment in the usual way, from among those who have reason to have had special experience useful in this project.

Upon motion, duly seconded, the foregoing recommendations were approved.

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188	338	700	1250	1800
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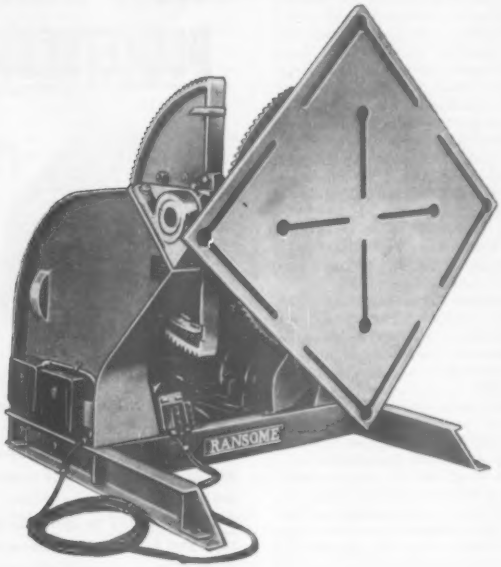

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Whether you produce "thousands alike" or "every one different", benefit from *increased arc-time* with Worthington-Ransome Welding Positioners. With just one set-up, the work is clamped to the table top. Then push-button controls or simple hand cranks do the work of tilting or rotating into any position convenient for economical downhand welding. Your welder can continuously weld without costly time and labor wasted in frequent rehandling of the work.

Result—up to 50% more footage, *better* welds (using higher current and heavier rods), less welding rod waste.

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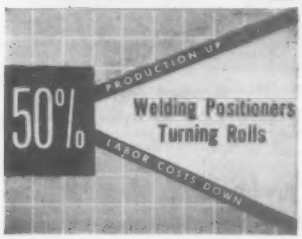

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(Above) Tube and Pipe-bending machine manufactured by Pandjiris Weldment Co.

(Left) Gibs on slide block forming dies are "bronze-faced" with Ampco-Trode.

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On the basis that the Annual Meeting in 1952 must be held at the time of the Metal Show, a general outline for conducting such a Meeting was developed. The Committee proposes that the Meeting be carried out on about the same plan followed in the past except that the technical program include a reduced number of papers, and that all meetings, of whatever nature, be organized, conducted and coordinated by a reorganized Program Committee. The total program should be considered to include all of the following events: Adams Lecture, Annual Business Meeting, Board of Directors' Meeting, Dinner and Awards, Educational Lecture, Ladies' Program, Plant Visit, President's Reception, Section Officers' Dinner & Conference, Technical Papers, Welding Research Dinner & Conference and 1/2 day—no scheduled events.

It is suggested that no committee meetings be scheduled of either technical or standing committees with the exception of those meetings required of those committees (Program, Convention or Manufacturers) that are necessary in order to conduct the Annual Meeting or associated exhibits.

Considering technical papers for presentation in 1952 this Committee is of the opinion that only 42 papers should be scheduled for presentation. The Program Committee would arrange all the details of the technical program. The possibility of specifying the subjects and the authors was considered and rejected as an exclusive policy. It is strongly recommended, however, that an experimental trial of program control, by inviting authors to speak on a chosen subject, be arranged. The Committee recommends that at least 12 papers in the 1952 season be programmed on this basis. It is further recommended that the subject for each technical session be chosen by the Program Committee and that a general invitation be issued to the membership to suggest papers for these sessions. The Program Committee would then choose the final author on the basis of a synopsis of his paper or his activity in the particular field concerned.

Regional Meetings

A specific lack in our present system is the fact that no formal way exists either to control or help arrange a presentable program at the regional meetings which are conducted in various parts of the country to meet the growing need for these activities. Specific reference is made to the A.W.S. program arranged in conjunction with the West Coast Metal Show. Other examples are the Ohio State Welding Conference, Purdue Welding Conference, the regional meetings at Buffalo, Cleveland, Detroit and some other cities, the A.I.E.E. Welding Meeting and possibly the various Welding Clinics.

This Committee believes that our SOCIETY should be more closely identified with these projects. The SOCIETY can provide a service in assisting in the arrangement of a good program for such meetings. In the long run, benefits in the way of increased A.W.S. membership should be obtained. Money to support such meetings financially is not available

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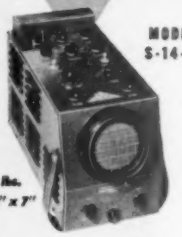

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at the present time, consequently the means to cover the expenses for each meeting must be arranged in the locale of the meeting.

In order to handle this work it is suggested that the Program Committee be reorganized to provide a main committee which will decide which events or meetings the Society will cooperate in handling. Subcommittees would then be set up to handle the details for arranging technical programs for each meeting.

Some discretion will need to be used in determining the specific activity of A.W.S. in this field. This Committee does not feel that a rigid pattern can be established in the outset. But it does feel that such activities should be encouraged and helped. The present pattern does not provide effective help.

It was recommended that the Society proceed with the organization of an Annual Meeting program for the years 1952 and 1953 to include the events listed in this report and to arrange the technical program as suggested.

Upon motion, duly seconded, the foregoing recommendation was approved with the following addition: "This is intended to include participation and assistance in selected regional meetings."

Assistant Journal Editor

A. G. Oehler, Chairman of The Welding Journal Committee, advised that at a meeting of The Welding Journal Committee held July 11th, it was unanimously voted to recommend to the Board that arrangements for employing Mr. Rossi part time for one day per week be consummated, effective Oct. 1, 1951. If at the end of a year it seems to Secretary Magrath, Editor Spraragen and also to Mr. Rossi that the selection has been a wise one, the arrangements may be renewed for an additional two-year period, with full employment starting at the end of three years. He amplified the reasons for the need of training a successor to The Welding Journal Editor, the advantageous proposition developed due to Mr. Rossi's present employment with the Pressure Vessel Research Committee enabling him to continue in that activity and devote one day per week on the basis of trainee for the position of The Welding Journal Editor.

Upon motion, duly seconded, the foregoing recommendation was approved.

By-Law Change

H. O. Hill, member of the Constitution and By-Laws Committee, reported for his Committee. The Committee submitted the following recommendation for the wording of Article IV, "Dues and Fees:"

"Section 3.—Date of Payment—All dues shall be payable in advance and shall cover the period of one year from the first day of the month in which a member joins, excepting that individuals or organizations paying dues for one or more individuals may designate the preferred date for payment."

Discussion followed as to the advisability of the date payable being the "first" day of the month or the *last* day of the month. After discussion it was decided that the Board was in favor of changing the by-law recommendation to the "last" day of the month.

Award of Merit

The Report of the Committee of Awards, as circulated to all Board members, was reviewed.

This report indicated that all members of Committee on Awards have unanimously approved the following statements:

Honorary memberships are well established within the national organization, and some other form of honoring a local member should be considered.

An honorarium in recognition of gratuitous or professional services is usually of such nature that custom or propriety forbids any price be set.

Many of the local technical sections have followed the practice of presenting token gifts, such as Past-Chairman pins, book ends or suitably engraved gavels, but these have been local contributions originating within a local committee or group.

An Award of Merit, given to A.W.S. members so qualified by distinguished or meritorious service as to warrant special recognition by a local section, might well be a written token of appreciation. It is felt that the presentation of a suitably inscribed certificate, printed on good parchment, either framed or suitable for framing, would be appreciated by a man who has given freely of his time to the Society. The cost of the certificate and the necessary additional lettering might easily be borne by the Local Section wishing to honor one or more of its members. Such a certificate probably should

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not be standard, but should be identified by the contributions of any particular member. Such a scroll should not be confused with the certificate issued by the National Headquarters in recognition of retiring National Officers and Directors. Still, it should be more distinctive than the membership certificate available to any member of the SOCIETY.

Upon motion, duly seconded, it was voted to accept the report of the Committee on Awards and instruct the Secretary to advise the Secretaries of all A.W.S. Sections of the Committee on Awards' recommendations. The activity was not to be one conducted by the National Society nor should National Society recognition be given. The award was to be given on the basis of A.W.S. Section recognition.

The Assistant Secretary reported that as of July 31, 1951, the SOCIETY had a total registration of 7323 consisting of 7225 active members and 98 delinquent members. As of July 31, 1950, the SOCIETY had a total registration of 7136 consisting of 6986 active members and 150 delinquent members.

For the 11-month period Sept. 1, 1950–July 31, 1951, the membership registration has increased from 7132 to 7323 or a net addition of 191 members.

During the first 27 days of August 1951, the SOCIETY enrolled 59 new members including one Sustaining Membership.

PERSONNEL

Bruckner Wins 1951 Lincoln Gold Medal

Dr. Bruckner won the 1951 Lincoln Gold Medal Award for his paper entitled, "The Micro-Mechanism of Fracture in the Tension Impact Test," as published in the September 1950 Supplement to THE WELDING JOURNAL.

Walter H. Bruckner

Biographical Sketch

In January of 1938 Walter H. Bruckner became a member of the staff in the Department of Mining and Metallurgical Engineering of the University of Illinois. He has served continuously as a staff member to the present time. His present rank is that of Research Associate Professor of Metallurgical Engineering with duties entirely in the research field except for a teaching assignment consisting of the presentation of a course of instruction in the Metallurgy of Welding for one semester of the school year. He has been an author or co-author of many papers most of which have appeared in past issues of THE WELDING JOURNAL. The subjects of the papers which have been published in the JOURNAL range from fatigue, weldability to fracture and strain-aging. He is a member of long standing of the University Research Committee of the Welding Research Council.

He is a graduate of Columbia University and received from that institution the A.B. and Ch.E. degrees; the latter degree was conferred in 1930. His interest in welding began in 1935 with an assignment at the Naval Research Laboratory, Washington, D. C., to a research project to determine the weldability of iron alloys. The weld quench test resulting from this work was presented to the A.S.-T.M. in 1938 and subsequently in THE WELDING JOURNAL.

His professional memberships include the AMERICAN WELDING SOCIETY, the American Institute for Mining and Metallurgical Engineers, the American Society for Metals and the American Society for Naval Engineers. Honorary memberships include Sigma Xi and Epsilon Chi.

Resistance Welding Prize Awards

The 1951 RWMA Jury of Award met in New York on August 9th and made the following selection for prize winning papers.

Category No. 1—Papers from an industrial source: 1st Prize Award to the paper entitled "Resistance Variations During Spot Welding" by W. L. Roberts. 2nd Prize Award to the paper entitled "Design and Operation of High-Speed Production Tube Mills" by D. H. Fleig. 3rd Prize Award to the paper entitled "Seam Welding Containers Automatically" by C. S. Seltzer.

Category No. 2—Papers from a university source, whose author is an instructor, a graduate student or a research fellow: 1st Prize Award to the paper entitled "Spot Welding of Scaly Heavy Gage Structural Steel" by E. F Nippes and J. N. Ramsey. 2nd Prize Award to the paper entitled "The Projection Welding of 0.010 and 0.020-In. Steel Sheet" by E. F. Nippes, J. M. Gerken and J. G. Maciora.

Category No. 3—Papers from a university source, whose author is an undergraduate: Prize to the paper entitled "Resistance Welding" by W. Colbert.

Biographical Sketches

WILLIAM L. ROBERTS

Born in Lincoln, England, on May 28, 1920, William L. Roberts attended Emmanuel College, Cambridge, as a holder of three scholarships. He obtained a first-class honors B.A. degree in The Natural Sciences Tripos in1941 and an M.A. degree in 1944.

Since leaving the university in 1941, Mr. Roberts has worked mostly in the field of electronics. From 1941 to 1946, he was employed at Telecommunications Research Establishment (then a department of the Ministry of Aircraft Production) at Swanage, Dorsetshire, and Great Malvern, Worcestershire, England. During these years he assisted in the development of "Oboe," a highly accurate radar bombing system.

In 1946, he jointed the Standard Telecommunications Laboratories at Enfield, Middlesex, to work in the field of electronic switching and a year later emigrated to the United States to join the Federal Telecommunications Laboratories (also a subsidiary of the I.T. and T system). At F.T.L., he aided in the development of an airborne radar device.

In 1948, Mr. Roberts joined the Nuclear Physics and Electronics Dept. of the

William L. Roberts

Westinghouse Research Laboratories, East Pittsburgh, Pa., as a Research Engineer. He was assigned to handle electronic and instrumentation problems encountered in the Welding Research Laboratory.

He received his U. S. citizenship in 1949 and is a graduate of the Institution of Electrical Engineers, a Fellow of the Physical Society and a Member of the American Institute of Electrical Engineers. Mr. Roberts won the first prize for a paper from an industrial source.

DONALD H. FLEIG

Donald H. Fleig, winner of the second prize for his paper from an industrial source, graduated from Armour Institute of Technology in Chicago (now Illinois Institute of Technology) in 1936 with a B.S. degree in Electrical Engineering.

He worked briefly for the Armour Research Foundation on a project to determine the electrical properties of steel wire and strand for rural electrification. This resulted in a position as development engineer with the Bethlehem Steel Co. in

Donald H. Fleig

Bethlehem, Pa. In 1939 he was advanced to the position of Patent Engineer, specializing in electrical patents.

During the war years he became a Materials and Process Engineer with the Goodyear Aircraft Corp. in Akron, Ohio. Here he was engaged in the application of resistance welding to the fabrication of aircraft and in research and development work on the resistance welding of aluminum alloys with stored energy welders. In 1947 he joined the American Electric Fusion Corp. as their Electrical Engineer in charge of research and electrical design of resistance welding equipment.

He is a member of Eta Kappa Nu, honorary electrical engineering society and of the AMERICAN WELDING SOCIETY.

C. S. SELTZER

C. S. Seltzer, winner of the third prize for an industrial source paper was born in Philadelphia, Pa. He received his Technical education at Cooper Union, New York City. His early engineering experience was in the field of automatic metal cutting tools. His later engineering experience included the engineering, design and special technical supervision of the installation of automatic container making equipment for the American Can Co., New York City and other well-known container producers. This covered a period of approximately twenty-five years and, geographically, all important manufacturing centers in America and part of Europe. This experience later formed the background for the development of automatic container equipment in the resistance welding industry and covered approximately fifteen years. A few noteworthy achievements are: the first automatic roll forming and seam welding machine for steel pails, also other high-speed container welding equipment; the rotor-type seam welder for small, light-gage round packages at high production speeds and the introduction of dry disk rectification to the container welding industry for high-speed seam welding. These welding activities were in association with prominent welding equipment producers in Warren, Ohio, and Detroit, Mich.

DR. ERNEST F. NIPPES

Dr. Ernest F. Nippes, co-author of the papers winning first and second prizes from a university source, was born in New York City, Feb. 1, 1918. He received his Bachelor's degree in 1938, his Master's degree in 1940 and his Ph.D Degree in 1942—all from Rensselaer Polytechnic Institute. He stayed with that Institution and served successfully as Instructor of Metallurgical Engineering, Assistant Professor and is at present Associate Professor of Metallurgical Engineering and also Supervisor of Welding Research. He has served as Consultant with some 15 concerns, being at present with the Adirondack Foundries & Steel, Inc., Watervliet, N. Y. His Society membership includes Sigma Xi, Tau Beta Pi, Phi Lambda Upsilon, American Society for Metals, AMERICAN WELDING SOCIETY and American Institute of Mining of Metallurgical Engineers. He has published more than twenty papers in the field of physical metallurgy and particularly in electric arc and resistance welding.

J. N. RAMSEY

John N. Ramsey, co-author of the paper winning first prize from a university source, was born in Independence Mo., Jan. 3, 1923. He entered the Ordnance Branch of the U. S. Army in November 1942, was transferred later to the Army Air Force from which he was honorably discharged in February 1946. At that time he entered Rensselaer Polytechnic Institute and was graduated in 1949 with the degree of B.S. in Physics. He continued working at Rensselaer on spot weld-

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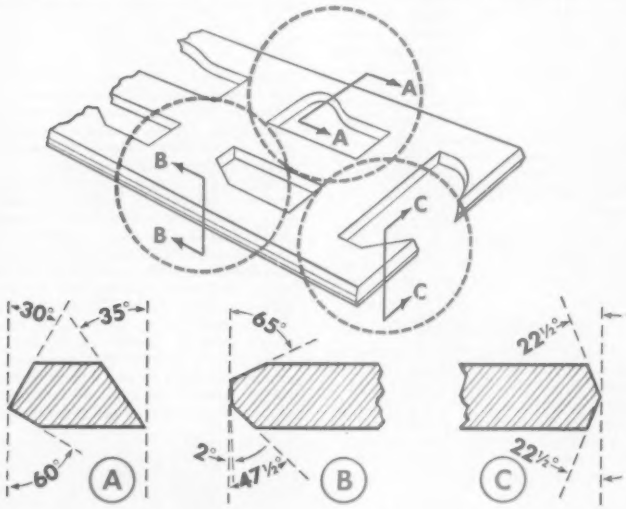

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ing of scaly heavy-gage structural steel and sintering with a liquid phase in the Fe-Cu system, and received his Master's degree in 1949. He is a member of the following Honorary Societies: Sigma Xi and Phi Lambda Upsilon. He is a candidate for a Ph.D degree and is currently preparing a thesis on the equilibrium diagram of chromium-oxygen.

J. M. GERKEN

John M. Gerken, co-author of the paper winning the second prize from the university source, was born in Jersey City, N. J., Sept. 3, 1920. He worked at the International Nickel Co. Research Laboratory in Bayonne, N. J. as a Junior Metallurgist from 1939 to 1942 and during the same time attended Newark College of Engineering, Evening Division. Mr. Gerken served three years with the Army Signal Corps. He continued his education at

J. M. Gerken

Rensselaer Polytechnic Institute and received his Bachelor of Metallurgical Engineering degree in January 1949. Mr. Gerken remained at R.P.I. as a research engineer working on welding problems. He received his Master of Metallurgical Engineering degree in January 1951. He is a member of the Northern New York Section of the AMERICAN WELDING SOCIETY, Eastern New York Section of the American Society for Metals, Tau Beta Pi and Sigma Xi.

JOSEPH G. MACIORA

Joseph G. Maciora, co-author of the paper winning second prize from a university source, was graduated from Hillyer College, Hartford, Conn., with a degree of Associate of Science in Engineering in June 1943. He was called to active duty with the U. S. Air Force in May 1943 and received Radio-Electronics-Radar training at several Air Force training schools. Upon completion of these courses, he was assigned to the Boca Raton (Florida) Air Force Base maintenance unit.

Upon release from active duty in 1946, Mr. Maciora resumed his studies at the Polytechnic Institute of Brooklyn and

Joseph G. Maciora

graduated with a Bachelor of Metallurgical Engineering degree in June 1948.

For the next seven months he was employed by Wright Aeronautical Corp., Wood Ridge, N. J. as a Junior Metallurgist. In March 1949 Mr. Maciora became a Research Fellow at Rensselaer Polytechnic Institute and continued graduate work in Metallurgy and Welding. He left R.P.I. in June 1950 for employment as a welding metallurgist with the Bridgeport Brass Co., Bridgeport, Conn. Mr. Maciora recently joined the staff of Bridgeport-Lycoming Division, Avco Manufacturing Corp. as a welding metallurgist.

Mr. Maciora is a member of the American Society for Metals, American Institute of Mining and Metallurgical Engineers as well as the AMERICAN WELDING SOCIETY.

WILLIAM H. COLBERT

W. H. Colbert is the first author to win an undergraduate prize award for his paper on resistance welding. He was born near Falmouth, Ky., Jan. 23, 1923. In June 1941, Mr. Colbert graduated from the Falmouth High School. After working at the Cincinnati Milling Machine Co. in Cincinnati for fifteen months he attended

William H. Colbert

two quarters of school at the University of Kentucky. From 1943 to 1946 he was in the Army Air Force as a fighter pilot and served overseas in India and China. Upon his discharge, Mr. Colbert enrolled in the College of Engineering at the University of Cincinnati where he studied Mechanical Engineering under the cooperative educational system. While attending the University, he became a member of the student branch of the American Society of Mechanical Engineers and has since become a junior member. Mr. Colbert started his co-op work at the Precision Welder and Machine Co. of Cincinnati in June 1947, and has continued under their employ since receiving his degree in June 1951.

Engle Promoted

A. D. Engle, a key member of The Austin Co.'s Engineering staff since 1920 and its district engineer at Chicago since 1945, has been appointed assistant vice-president for research, according to an announcement by George A. Bryant, Austin president. Engle will be responsible for special engineering research work and certain foreign assignments, with headquarters at the company's general offices in Cleveland, where he will work directly with J. K. Gannett, vice-president and director of engineering and research.

George Miller, Austin's coordinating engineer on Atomic Energy Commission work at Oak Ridge since 1948, succeeds Engle as Chicago district engineer.

Engle, a native of Cleveland, was graduated from the U. S. Naval Academy at Annapolis and subsequently pursued graduate studies at Case Institute and Massachusetts Institute of Technology. He joined the Austin organization in 1920 as assistant to the chief engineer and subsequently served as New England representative and was in charge of the company's work in China. As director of research from 1936 to 1942 he played a prominent role in development of welded designs and in extension of controlled-conditions principles which were applied

A. D. Engle

in the huge Fort Worth and Tulsa aircraft plants for which he served as chief engineer and at the Oklahoma City aircraft plant where he was project manager.

Engle is registered as a professional engineer in 19 states. He is a member of THE AMERICAN WELDING SOCIETY, The American Society of Civil Engineers, Society of American Military Engineers, American Concrete Institute, National Bureau of Engineering Registration, Illinois Society of Professional Engineers and the Oklahoma Engineering Society.

Miller, a native of Coeur d'Alene, Idaho, and civil engineering graduate of the University of Idaho, joined the Austin staff in Seattle as a structural engineer in 1940 and played a prominent part in development of plans for naval-training facilities, submarine-fueling stations and other installations under the 75-million-dollar Navy contract covering work over a 300-mile radius in the Pacific Northwest. Prior to joining Austin, he was successively engaged as office engineer for the Portland Cement Assn. at Spokane, as structural engineer for the City of Tacoma and as chief engineer (Idaho) of Public Works Administration at Boise, Idaho. He is an associate member of the American Society of Civil Engineers and a member of the Idaho Society of Engineers.

Hartbower Award

Lt. j.g. Carl E. Hartbower, C.E.C., U.S.N.R., has won Special Honorable Mention in the competition for the Annual Award of the Chief of Navy Civil Engineers, it was announced by Rear Adm. Joseph F. Jelley, C.E.C., U.S.N., in whose honor the award is given. The Annual Award is presented for the best technical paper by a Civil Engineer Corps officer about some aspect of C.E.C. work. Lt. Hartbower's award, which includes a cash prize of $25, was given for his paper entitled, "The Distribution of Strain in Weldments Under Combined Loads."

A more extensive report on this subject, written by Lt. Hartbower and W. S. Pellini, was subsequently published in THE WELDING JOURNAL, 30 (6), (June 1951), under the title, "Explosion Bulge Test Studies of Weldments."

Top Award in the Chief's Award competition went to Lt. Charles B. Coyer, C.E.C., U.S.N., of Jamestown, N. D., for a paper entitled, "A Multi-Purpose Wave Generator." Lt. Coyer's award included a $100 cash prize.

Lt. Hartbower, who is now on inactive duty, is a metallurgist at the Naval Research Laboratory, Washington, D. C., where the work described in these articles was performed.

A native of Boston, Mass., he graduated from Worcester Polytechnic Institute, Worchester, Mass. During the war he was a Chief Specialist in the Navy. Discharged in 1947, he enlisted in the Naval Reserve and received a Reserve Commission in the C.E.C. He has since taken an active part in Construction Battalion Reserve work.

In his civilian career Lt. Hartbower has specialized in welding engineering, and has been co-author of several previous articles which have appeared in THE WELDING JOURNAL. These include: "A review and Summary of Weldability Testing," "Effect of Welding on Transition Temperature," "Mechanical and Material Variables Affecting Correlation," "Effect of Titanium and Vanadium on Notch Sensitivity and Weldability in Low-Alloy Steel" and "Investigation of Factors Which Determine the Performance of Weldments."

Lincoln Electric Appoints New Chief Engineer

L. K. Stringham has been appointed Chief Engineer for The Lincoln Electric Co. of Cleveland, Ohio. G. G. Landis continues as Engineering Vice-President.

L. K. Stringham

Stringham, an electrical engineer and graduate of Cornell University, has been with Lincoln since 1933. He has worked continuously in the engineering department where his experience has included experimental research as well as product development and application. He has worked on the design of welding machines as well as electrodes and fluxes, for both manual and automatic welding. During the last ten years his development work in fused and agglomerated fluxes has been important in extending the uses of the hidden arc-welding process. He has also been responsible for the development of equipment for the manual and semi-automatic application of this welding process.

It's America's most popular gift—given by more than 12,000,000 American families!

Yes, the Double-Barred Cross stands for *Christmas Seals* . . . that make possible the greatest gift of all, health, life itself . . . in the truest sense of Christmas giving.

Your Christmas Seal dollars help make possible the year-round control of America's worst infectious disease—*tuberculosis*. Thus, *you help protect your own family, friends, and community.*

So please remember *the gift that's given most and gives the most*—most everyone does. Send in your contribution today.

buy Christmas Seals!

Because of the importance of the above message, this space has been contributed by

THE WELDING JOURNAL

For the past two years he has been Director of Welding Development. He is on the Board of Directors of The Lincoln Electric Co., a member of the N.E.M.A. Navy Committee for the Development of Low Hydrogen Electrodes, a member of A.W.S.-A.S.T.M. Committee for Filler Metal. He is a Fellow in the American Institute of Electrical Engineers, a member of the AMERICAN WELDING SOCIETY, and the electrical honorary society, Eta Kappa Nu. He lives at 2700 Endicott, Shaker Heights, Ohio.

Vinson Made Assistant Manager

Arthur F. Vinson, of Townsend, Mass., has been appointed assistant manager of the General Electric Co.'s Manufacturing Services Division, Nicholas M. DuChemin, division manager, announced recently.

Mr. Vinson, formerly manager of employee and community relations of General Electric's Small Apparatus Division, with headquarters at Lynn, Mass., will be located in Schenectady.

A native of Plainfield, Ill., Mr. Vinson was graduated from Michigan State College in 1929 with a B.S. degree in electrical engineering. He joined G.E. as a student engineer on the company's Test Course at Fort Wayne, Ind., and then held successive positions as process engineer, d.-c. motor section head and inventory control supervisor.

In 1939 he was named assistant production manager at the Fort Wayne Works, a position he held until 1945, when he was transferred to Schenectady as assistant production manager of the company's Apparatus Department. He was appointed chairman of the committee in charge of the former Welding Equipment Divisions in 1947, and a year later became manager of the Welding Divisions, with headquarters in Fitchburg, Mass.

L. R. Jackson Named Assistant Director at Battelle

Lloyd R. Jackson has been named an assistant director of Battelle Institute, Columbus, Ohio, according to an announcement by Director Clyde Williams. He will handle research coordination.

The new assistant directorship, according to Dr. Williams, results from the increasing demand by industry and government for Battelle research. Dollar volume in 1951 will exceed nine million dollars, compared with last year's six and three-quarter millions.

Mr. Jackson is known particularly for his work on the engineering properties of materials. He has been associated with much of Battelle's research on fatigue, creep, plastic flow and structural analysis, and is author or co-author of more than 40 technical papers. For several years he has been active in the work of engineering societies. He has served on committees of the American Society for Testing Materials, AMERICAN WELDING SOCIETY, Research and Development Board, National Advisory Committee for Aeronautics, American Society for Metals and the Column Research Council. He is also a member of the American Physical Society and Sigma Xi, science honor society.

A graduate in electrical engineering from the University of Colorado, Mr. Jackson received the Master of Science degree in physics from Yale University in 1932. Before joining the Battelle staff in 1935, he was a member of the research staff of the Jones and Laughlin Steel Corporation.

Employment Service Bulletin

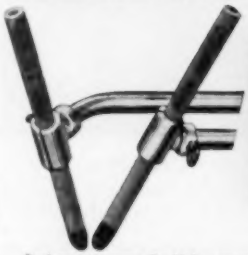
Services Available

A-621. Position desired as Welding Engineer. Two years' experience as Resistance Welder Maintenance Overseer with large metal-fabricating concern including redesign of welders and weldments for good welding and reduced maintenance. Seven years' experience as field service engineer with Resistance Welder manufacturer; aircraft quality welding a specialty. Permanent non-travel position desired in resistance-welding field. Chicago area preferred.

A-622. Arc welding Inspector or Supervisor. Age 51. Certified welder. American born. Ten years field experience on pipe and tanks.

BECKER

KEEN-ARC CARBONS



FOR CONSISTENTLY GOOD RESULTS

Designed to carry the high currents necessary for intense heat, BBB Keen-Arc Carbons produce a fine-grained weld of high tensile strength. They give a smooth, steady "flowing" flame which does not wander and which is concentrated at the desired focal point. Flame temperature is easily and accurately adjusted by merely changing the ampere input, and heavy copper coating permits gripping at extreme ends—eliminates frequent and periodic resetting.

A COMPLETE LINE OF CARBON WELDING SUPPLIES including carbon and graphite electrodes, carbon rods and plates, welding paste, etc. Write for catalog.

BECKER BROTHERS CARBON CO.

3450 South 52nd Ave. Cicero, SD, Illinois

Now...

ARC-DRIVE CONTROL for D-C Rectifier Welder

...Instantaneous response to arc-load changes
...Instantaneous recovery
...Reduced arc blow
...Completely adjustable by operator

Westinghouse RA Welders with new positive arc-drive control now prevent shorting when used on "drag" welding applications. In addition, they allow complete penetration on root passes of vertical and overhead welds. Arc-drive control is obtained by adjusting the ratio of short-circuit current to welding current without changing open-circuit voltage. Actual amount of arc-drive current can be varied by the operator.

For information on this improved RA Welder or other Westinghouse Welding Equipment, write Westinghouse Electric Corporation, Dept. DC80, Welding Division, Buffalo, New York. J-21607-A

YOU CAN BE SURE... IF IT'S Westinghouse WELDING EQUIPMENT

Simplified Precision Welder Control

for easier maintenance and increased dependability

Class 8993 NEMA Type S2H Synchronous-Precision Controller available with 600 or 1200 frame contactor. Can be arranged either for side of machine or wall mounting.

DESIGN LEADERSHIP

APPLICATION: *for welding stainless steel, nonferrous metals, and other critical spot welding jobs requiring electronic synchronous-precision control. (Available with current wave shape control auxiliaries for aluminum or alloy metals.)*

DESIGN LEADERSHIP features

Easier Maintenance . . . greatly simplified circuits require fewer tubes and only one operating relay (for the air valve).

Increased Dependability . . . all components designed specifically for industrial welder service. Tube circuits are fail-safe and initiating contacts are in isolated 24 volt circuit which supplies power to the valve relay.

Consistent Accuracy . . . regulated DC voltage on tube control grids compensates for supply fluctuation or tube variations . . . assures timing accuracy.

Greater Accessibility . . . timer, heat control and firing panels designed for easy inspection and maintenance, with quick fasteners and plug connectors.

***Write* for BULLETIN 8993**
or consult your nearby Square D Field Engineer

SQUARE D COMPANY

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SQUARE D COMPANY CANADA LTD., TORONTO • SQUARE D de MEXICO, S.A., MEXICO CITY, D.F.

NEW PRODUCTS

New Type Starter for Arc Welders

A new type starter, basically a fused high-capacity interrupter switch, is now being used on all production models of General Electric's Type WD-42, WD-43 and WD-44 motor generator d.-c. arc welders.

According to G-E engineers, the new starter provides positive motor starting because the contacts are locked in by mechanical action. A direct-acting lever physically closes or opens the contact when it is operated, affording direct control over starting and stopping. This reduces maintenance by eliminating intermediate devices (circuit coils, magnetic contacts) which might fail or malfunction. It also reduces pitting and erosion on contact tips by eliminating chattering or misstarts, they said.

A time-delay fuse connected directly in the line protects the motor circuit from overload. This time-delay feature enables the fuse to carry harmless overloads and starting circuit inrushes, as well as providing motor-running and branch circuit over-current protection, as permitted by Section 4346 of the 1947 Electrical Code.

The new starter is mounted on the end panel of the welder control box, which has been redesigned to allow easy access to the fuse and connection terminals.

"Form-A-Jig" Compound

A new plastic-cement compound, "Form-A-Jig," which will not deform, move, or swell during welding operations as it holds the component parts together has been announced by Eutectic Welding Alloys Corp., Flushing, N. Y.

This new product is claimed by the manufacturer to be a swift, simple, inexpensive substitute for a metal jig, ideal for assembling small lots where there is no time for elaborate jig construction.

"Form-A-Jig" compound not only holds parts for welding, brazing and soldering, but may also be used to hold broken sections together for tool salvage and similar maintenance; for shielding or protecting from flame at any time; for working with heat-treated or enameled sections; or as a mold for low-melting metals such as Babbitt, solder, lead, aluminum, etc.

This new compound will not soil metal, does not mar the surface, does not corrode. It is equally easy to use with fingers or tools—just the right consistency, it is claimed, for effortless placement and "setting."

Complete details may be obtained by writing for Leaflet 545P to Eutectic Welding Alloys Corp., 172nd St. and Northern Blvd., Flushing, N. Y.

Electrode Holder

The Caddy holder features the welding cable connected by the Cadweld process and is available in 300 and 500 amp. capacity.

The Caddy holder is:

1. Designed for the comfort of the welding operator. (*a*) Spring-assembly engineered to give a uniform pressure when inserting or ejecting electrodes. (*b*) Handguard that protects the welder's hand from spatter, arc and reflected heat. (*c*) Cooler. Greater heat dissipation by a newly designed channel construction of the body gives twice the surface area yet retains maximum strength.

2. Designed for mechanical and electrical efficiency. (*a*) Connection of the cable to the stud by the Cadweld process gives a solid copper circuit from welding machine to electrode holder—no hot spots. (*a*) Replaceable stud. After cable is worn and ready to be changed, the old cable with stud attached may be cut off and the cable Cadwelded to the new stud. (*b*) Deeply grooved jaw for maximum rod grip. (*c*) Enclosed coil-spring assembly, completely protected inside the handle—no chance of damage by arcing or spatter.

Erico Products, Inc., 2070 East 61st Place, Cleveland 3, Ohio.

Stabilizer Safeguards Low-Hydrogen Electrodes

The low-hydrogen welding electrode, a comparatively recent development, is a scientific achievement which has made possible the successful *manual arc welding* of steels with a high-alloy content and other hard-to-weld characteristics.

Unfortunately, the shielding of low-hydrogen electrodes is inherently thirsty. In fact, if exposed to normal shop atmosphere for only a short time, it will absorb sufficient moisture from the air to exceed allowable limits, thereby destroying the low hydrogen quality. That is why low-hydrogen electrodes are packed in moisture-proof containers.

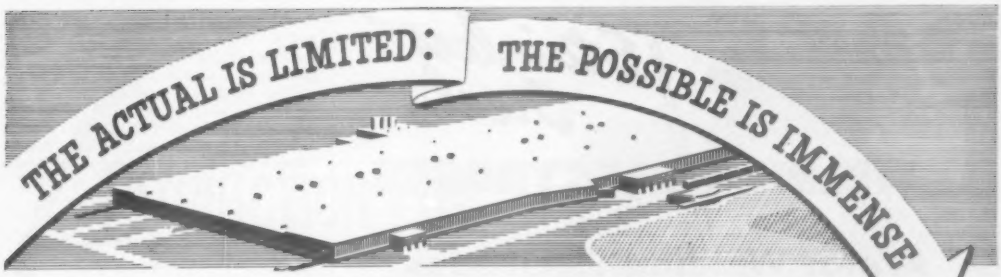
With the rapidly increasing use of the low-hydrogen welding process, it has become necessary to find some means of protecting the electrodes from atmospheric moisture from the time they are removed from the moistureproof container until they are put into use. Many makeshift methods and devices have been tried with varying degrees of success or failure.

A compact, efficient, moisture-content stabilizer has been introduced which provides the desired protection of low-hydrogen welding rods at point of use. It is known as the Blueweld "Lo-Hydrogen" Electrode Stabilizer and, according to the manufacturer, is designed "to keep low-hydrogen electrodes truly *low hydrogen*." The Blueweld unit stores 400 lb. of electrodes and, because of its size and compact design, may be located at any point convenient to the welding operation. Operators are always sure of low-hydrogen rods of proper moisture content. Literature is available from the manufacturer, Fred C. Archer, Inc., 606 W. Wisconsin Ave., Milwaukee 3, Wis.

Metallizing Guns

High-speed metallizing guns are expected to reduce many machine-part repair and salvage costs 85 to 90%—make 25–30-year corrosion protection of equipment and structures available to more users at lower cost.

Two new metallizing guns have recently been announced by Metallizing Engineering Co., Inc. The new guns, the Metco Type 4E for machine element work and the Type 5E for corrosion protection coatings, are said to develop the highest spraying speeds yet available in guns designed for hand-held operation. At the same time, the new guns provide the nearest thing to automatic operation yet devised, since they incorporate a patented jet-siphon principle in the gas head which automatically compensates for variations in gas pressure as high as 10 lb., and provides a steady, unvarying flame which produces uniform coatings at lower cost than previously possible. The new guns also incorporate automatic control of wire feed which compensates for kinks in the wire, reel stand drag, etc. The Metco Type 4E gun is designed to spray all wires from 20 B&S gage to $^1/_8$-in in any metal—carbon steels, stainless, Monels, bronze—at speeds up to 40% faster than previous models. The Type 5E is the first gun specifically designed for high-speed spraying of the softer metals, such as zinc and aluminum, for protection of equipment and structures against corrosion for periods ranging from 20 to 30



NEW LINCOLN PLANT CREATED BY INCENTIVE-INSPIRED CO-ACTION IN DEVELOPING POSSIBILITIES IN PRODUCT

© LE Co. 1951

DESIGN IN STEEL IMPROVES APPEARANCE

. . . lowers cost 15%

UTILIZING the economies of welded steel has cut the cost of this machine base by 15%, while achieving better sales appeal through its clean, modern appearance.

Following the features of the original base, as shown in Figure 1, the first design involved 13 separate components and required 205 inches of welding (Fig. 3). However, by taking full advantage of opportunities for simplifying details while increasing strength and rigidity, the final design, (Fig. 4) involved only 7 components and welding was reduced 40%.

Machining costs are cut sharply since welded components are formed close to finished dimensions. Changes in design for special needs of customers can now be accomplished without need for alterations in patterns.

Fig. 4—Present Design *has rigid box-type construction. Needs less material than Figure 3. Designers and Fabricators: The Boiler Repair and Welding Shop, Inc., Bridgeport, Connecticut.*

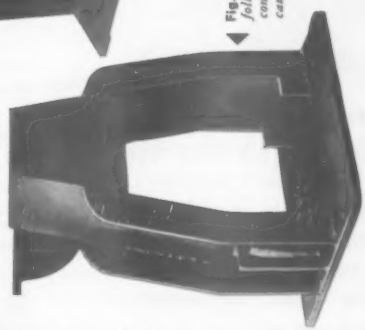


Fig. 3 — First Weldesign in Steel *follows appearance of original construction. Saves on metal because steel is stronger than iron.*

WELDED DESIGN ALWAYS IMPROVES PRODUCT AND LOWERS COST

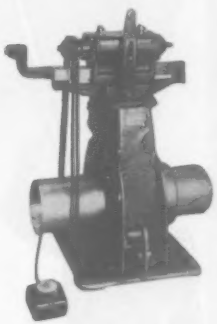


Fig. 1—Original Design *of wire straightening machine for the A. H. Nilson Company, Bridgeport, Connecticut. Required considerable machining, cleaning and finishing prior to painting.*

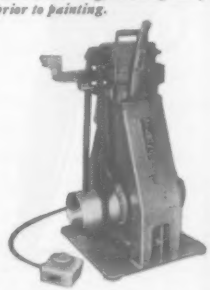


Fig. 2—Welded Design *costs 15% less. Has improved appearance . . . better selling appeal. Tests show base has greater rigidity than in original construction.*

HERE'S PROOF

Machine Design Sheets are available to designers and engineers. Simply write on your letterhead to Dept. 911,

THE LINCOLN ELECTRIC COMPANY

CLEVELAND 17, OHIO

PAGE *Stainless Steel*

WELDING ELECTRODES

Armor Welding Electrodes
. . . and All Standard Types
AC or DC . . . the BEST
. . . for any weld
on all types
of stainless steel

STAINLESS STEEL
has great strength . . . but its strength is limited by the quality of welds which seal the joints. In all kinds of manufacturing—military work in particular—stainless is being used more widely. If you weld stainless, choose electrodes with care.

PAGE STAINLESS STEEL ELECTRODES, AC or DC, give a stable arc under all conditions. The metal flows smoothly. Slag is clean and easily removed. The coating resists cracking down to very short stubs. Now available in 10-lb. lined, hermetically sealed metal cans which can be reclosed. ***Be sure . . . specify Page Stainless Steel Electrodes.***

ACCO
Manassas, Pa., Atlanta, Chicago, Denver, Detroit, Los Angeles, New York, Philadelphia, Portland, San Francisco, Bridgeport, Conn.

PAGE STEEL AND WIRE DIVISION
AMERICAN CHAIN & CABLE

PAGE WELDING ELECTRODES

years. The 5E gun sprays $^3/_{32}$-in. wire and will deposit as much as 55 lb. of zinc per hour, aluminum 15 lb per hour. The guns may be mounted for use on a lathe or other machine in production-line work, or may be used in hand-held operation, since they weigh only 4 lb., 12 oz.

For further information, contact Metallizing Engineering Co., Inc., 38–14 30th St., Long Island City 1, N. Y.

New Welding Electrode Saves Copper

A new type of resistance-welding electrode, marketed under the name Kaptrode, is announced by Weiger Weed & Co., 11644 Cloverdale Ave., Detroit 4, Mich., division of Fansteel Metallurgical Corp.

The electrode consists of an expendable cap which fits into a semipermanent adapter shank. This in turn fits into any standard Morse taper type electrode holder. Depending upon the length of the adapter shank, copper savings up to 75% are possible.

Kaptrode electrodes are made in six nose styles (pointed, dome, flat, offset, truncated cone and radius face), in three R.W.M.A. alloys (Classes 1, 2 and 3), and two Morse taper sizes (Nos. 1 and 2).

Adapter shanks are made at present in two Morse taper sizes and nine lengths ranging in $^1/_8$-in. steps from $1^1/_4$ to $3^1/_4$ in. Other lengths are manufactured to specifications. All Kaptrode electrodes fit interchangeably into any adapter shank of the corresponding Morse taper size, and project $^3/_4$ in. from the shank. Thus, with the proper shank length, it is possible to duplicate standard electrode lengths and use Kaptrode electrodes without changing established machine setups.

The Kaptrode electrode is fitted into the adapter shank by a blow of a rubber or rawhide mallet, or by pressure of the welding machine. Electrodes are removed with the Kaptrode extractor, a tool easily adapted from the familiar toggle pliers, or obtainable from Weiger Weed & Co.

Workout tests made in Detroit motor car plants show that under ordinary wear and tear of shop conditions, one adapter shank should outlast ten Kaptrode electrodes. At this rate, electrode costs are reduced 20% or more. Careful operators will get longer life from adapter shanks with proportionate increases in savings.

The use of Kaptrodes greatly reduces users' inventory stocks of resistance welding electrodes, constituting a further saving, both in costs and in copper.

Production Life Increased 900% by Hard-Facing Here

. . . and still no sign of wear!

A $\frac{3}{16}$-in. layer of HAYNES STELLITE hard-facing alloy protects this punch mandrel from severe wear and galling. The hard-faced mandrel, used in the manufacture of pipe couplings, has already produced 10,000 pieces and still shows no sign of losing gage. Tool steel parts in this same service wore out after punching only 1,000 pieces; and punches of case-hardened steel had to be replaced after producing 500 couplings.

The couplings are made from pipe of $\frac{1}{8}$-in. wall thickness and $5\frac{5}{16}$ in. diameter. Under a pressure of 20 tons, the pipes are expanded to $6\frac{7}{8}$ in. in diameter at the rate of one every two minutes. In this severe forming operation, the hard-faced ring on the mandrel stays out-to-gage 10 times as long as a tool steel ring and 20 times as long as a case-hardened steel ring. In addition, it does not gall and mark the inside diameter of the pipes.

Hard-facing is often the answer to serious wear problems in all types of machinery and equipment. By reducing wear at key points, it helps to cut maintenance costs and keep machinery running at peak efficiency. Write for the folder "Hard-Facing Materials Data" for a quick summary of HAYNES hard-facing alloys. It gives chemical composition, properties, uses, and forms of each alloy.

HAYNES TRADE-MARK *alloys*

Haynes Stellite Company
A Division of
Union Carbide and Carbon Corporation
UCC
General Offices and Works, Kokomo, Indiana
Sales Offices
Chicago — Cleveland — Detroit — Houston
Los Angeles — New York — San Francisco — Tulsa

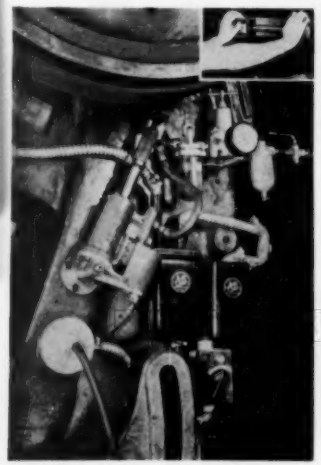
"Haynes" and "Haynes Stellite" are trade-marks of Union Carbide and Carbon Corporation.

Kaptrode electrodes, adapter shanks and extractors are described in detail in Technical Data Bulletin 14.100, obtainable from the manufacturer.

Punch Press Control

Punch Press Guard Model No. AE 60 is particularly designed for direct clutch presses having not more than 60 lb. pull and 2 in. of up and down movement on the clutch tripping rod. Model No. AE 60 is also adaptable to spot welders, brakes and shears. The unit is electric-pneumatic operated. Present foot treadle is replaced by an air clutch operator; a set of electric start buttons for each operator is installed in a convenient place on the press, the buttons are located far enough apart so that operator must use one hand on each button. Only by simultaneously pushing both buttons is the circuit completed, then the air clutch operator engages the clutch allowing the ram to make one complete revolution in the same manner as when tripped by the foot treadle. Both hands are out of the danger zone as ram descends, but are ready to pick up the next piece of work. The foot treadle can be either temporarily disconnected or permanently removed if desired. An Anti-Repeat Switch and Long Cam (Standard Equipment) will allow the ram to descend only once, unless the Solenoid valve is re-energized by use of the two start buttons. A foot attachment for handling of long stock may be furnished. Plugging it into the press for blanking purposes gives an automatic operation to the press, making start buttons inactive. A limit switch can be installed in the circuit on interlocking dies so that the press cannot be operated unless the die or work is in the home position.

Tech-n-Kal Machine and Engineering, 12925 Auburn Ave., Detroit, Mich.



Ryan Designs Simplified Spot-Welding Timer

Two Ryan employees have designed and built a better "brain" for spot-welding machines. Designated a sequence timing panel, this electronic device "tells" the spot welder what to do and when to do it.

Tired of the tedious job of checking intricate circuits of standard sequence panels, when trouble occurred, Eddie Duke and Bill Phillips, of Electrical Maintenance, decided to do something about it. They worked out plans for the kind of compact, simple type of sequence panel which maintenance men would welcome—and built it. The new panel is performing so well that Ryan is installing it on all spot-welding machines for which it is adapted.

The Duke and Phillips panel is not only more efficient and trouble-free than those available commercially, but it is much simpler to service and maintain. It is fabricated from a minimum number of readily obtainable parts which cost only a fraction of the price of panels which can be purchased. It is reducing to the absolute minimum the loss of valuable spot-welding machine time, due to sequence panel trouble.

With increasing tempo, the joining of aircraft structures is being accomplished by spot welding because of the vast improvement in the equipment. Modern spot-welding machines, costing $30,000 each, can form strong joints in aluminum and stainless steel alloys at the rate of up to 125 spot welds per minute. The successful performance of these giant tools is dependent upon the small electronic "brain," or sequence timing panel, which masterminds their work.

The timing panel automatically controls the exacting timing requirements for each phase of the sequence of spot welding. "Squeeze" time, "weld" time, "hold" time and "off" time must be perfectly coordinated and timed to an accuracy of one-half cycle, or 0.0083 sec., to obtain sound spot welds. Consisting of a series of relays and electronic tubes, the sequence timer is put into action when the machine operator steps on a foot switch.

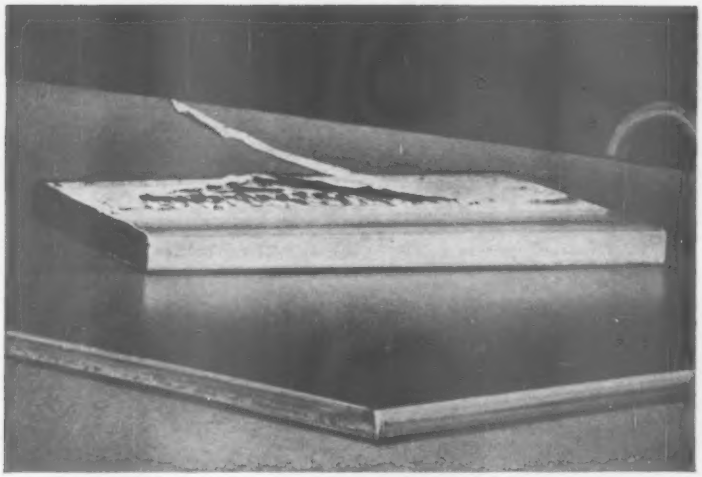
This action closes the first relay which actuates an air valve bringing the electrodes together under pressure and closing the second relay, which will time the "squeeze." As the second relay closes, it starts the welding current and trips the third relay which will time the current. Like a chain reaction, the third relay cuts the flow of current and actuates the fourth relay which will time the interval while the electrodes are held together to forge the material. The fourth relay also releases the air valve and trips the fifth relay which will measure the "off" time between the end of the operation and the next cycle. At the end of the "off" time, the first relay is automatically tripped and the cycle starts over again.

At a nominal rate of 70 spot welds per minute, all of these precision timing operations must take place within 0.8 sec. for each spot weld. The hair-splitting of this 0.8 sec. into exact intervals for each phase of the spot-welding cycle is the important task of the sequence timing panel. During an eight-hour day, it is possible to perform more than 30,000 spot welds on a single machine. That is why Ryan electrical maintenance men are interested in two basic requirements for sequence timing panels: accuracy and ruggedness.

In developing a simpler panel, Duke and Phillips eliminated two complete relays and tubes from the standard type circuits and designed their new unit with six relays and four tubes. For compactness and convenience, they used midget-

Eddie Duke (left), Ryan electronics troubleshooter, exhibits the new sequence timing panel which he and Bill Phillips (right), Ryan electronics expert, designed and built. Note more complex panel on welding machine

This weld in Nickel-Clad Steel shows the self-lifting slag which the "141" nickel electrode gives when there is a proper balance in the welding conditions.



New Inco Electrode for Nickel-Clad Steel

"141" Nickel Electrode makes possible high ductility in iron-diluted nickel welds

The new Inco "141" nickel electrode for Nickel-Clad Steel is a companion to the Inco "131" nickel electrode for solid Nickel. Its new core wire and new flux make it possible to obtain high ductility when welding the clad side of Nickel-Clad Steel... overlaying nickel on steel ...welding nickel to steel.

"141" is corrosion-resisting. Welds made with the "141" electrode on Nickel-Clad Steel or overlays on steel will have corrosion resistance comparable to that of solid nickel, providing adequate control is exercised over the iron dilution of the welds.

"141" meets Code requirements. Welds made with the "141" nickel electrode meet the requirements of the A.S.M.E. Unfired Pressure Vessel Code for construction of units covered by Case 896 (Clad Steels) and Case 1078 (applied linings).

Slag removal is easy, too. When the balance between heat input, speed of welding and iron dilution is right, the slag will lift from the weld about 3 inches behind the arc.

Mechanical Properties

(a) Nickel overlays on steel will have a minimum elongation of 30 per cent.

(b) Welds in the clad side of Nickel-Clad Steel will have a minimum elongation of 30 per cent.

(c) Welds in solid nickel will have a minimum elongation of 20 per cent.

(d) All weld metal tensile specimens (iron free) have the following properties:

Minimum yield strength (.2% offset) .....30,000 psi.
Minimum tensile strength .....65,000 psi.
(Hardness) Rockwell B 70-80

Like other Inco products, much of the "141" electrode production is being diverted to defense at present. However, Inco's Technical Service Section is always ready to help you with ideas and suggestions for your present production and future planning.

Write today, outlining your problems. Also, ask for your free copy of revised Inco Bulletin T-2, "Fusion Welding of Nickel and the High-Nickel Alloys."

INCO TRADE MARK

THE INTERNATIONAL NICKEL COMPANY, INC.
67 Wall Street, New York 5, N. Y.

sized relays which are interchangeable and installed in 11-pin tube-type sockets. Although small in over-all size, these relays actually have larger contacts than those used on standard relays. This permits them to carry more current and gives them longer service life.

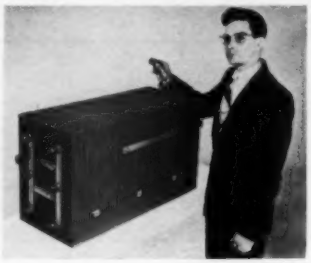
An important advantage of the new sequence timer is the fact that it can be used on any resistance spot welder of single-phase or stored energy type by simply installing or removing a jumper wire. With this facility, it is possible to standardize on one uniform type of panel for most machines. Electrical maintenance men can learn the circuits of this panel and be familiar with it when trouble arises without being faced with the task of trying to figure out several different types of panels which are installed on various machines. It is not unusual to find a valuable spot-welding machine tied up for 48 hr. while sequence panel wiring layouts are checked for trouble.

With the new standardized sequence panel, there is no need for taking a machine out of production for more than a few minutes because of timing panel trouble. Electrical maintenance simply removes the defective timer and installs another sound one which they have ready as a spare. This is readily accomplished because these panels are fitted with plug-in connection wiring and the procedure is tantamount to plugging an ordinary clock into a convenient outlet. Then, the faulty sequence timer may be taken to the shop and worked over at leisure.

Another benefit gained with the newly designed sequence panel is the elimination of imperfect spot welding due to operator error. With standard panels, it is possible for the operator to release the foot switch prematurely before the welding current has been cut and bring the forging pressure to bear during part of the weld time. This excess pressure prevents the formation of the spot weld. With the new panel it is not possible for the operator to commit this error because the circuits are so designed that the operator cannot alter the perfect, automatic behavior of the sequence timing after the cycle has been started. Each relay locks itself in and cannot be prematurely released because of operator error.

Selenium Rectifier Power Units

Syntron Co., 258 Lexington Ave., Homer City, Pa., manufacturers of selenium rectifiers, vibratory material handling equipment, portable power tools and other devices, announces the availability of new, custom-made a.-c. to d.-c. Rectifier Power Conversion Units of high current and voltage capacities.



This new development is made possible by the manufacture of extra large selenium rectifier cells by Syntron's new vacuum process. The use of these larger cells permits the use of fewer parallel elements for a given d.-c. output and at the same time keeps the weight to a minimum.

Additional information concerning Syntron Selenium Rectifiers and Power Units of these high power ratings is available from the manufacturer.

"Fillerweld"

"Fillerweld," a new product designed to speed alloy-metal welding on applications where filler metal must be added, has been announced by General Electric's Welding Dept.

Used with gas-shielded arc welders, Fillerweld allows the operator to control the continuous flow of filler-metal automatically by means of a finger switch mounted on the torch. According to G-E engineers, the new welding attachment allows the operator to start or stop the flow of filler metal without breaking the arc, resulting in a smoother, faster weld. Wide application is expected on food and

dairy equipment and in the fabrication of aluminum containers and light structural shapes.

Fillerweld consists of two main elements—the torch or "gun," and a mechanical power unit. The gun is basically a manual water-cooled inert-arc tungsten holder to which has been added a control switch, and a gear assembly for pulling the filler-metal from the spool to the arc through the gun. Rated at 250 amp., the gun accommodates tungsten from 0.040 to $^{5}/_{32}$ in. in diameter and up to seven inches long.

The mechanical power unit consists of a motor which provides the power for drawing the filler metal, a Thy-mo-trol* unit for controlling the motor, and a spool which holds the filler wire. The unit is mounted on a portable platform and can be moved easily from job to job.

To operate the new equipment, the operator merely presents the desired filler wire speed by means of a rheostat located on top of the Thy-mo-trol unit. He then takes the gun just as if it were a normal inert-arc torch and strikes the arc. As soon as a molten pool has been established on the base metal, the operator pulls the trigger on the gun and the wire feeds into the arc. To stop the wire feed at any time, even during welding, the operator has only to release the trigger.

*Reg. Trade Mark, General Electric Co.

UNITED STATES TESTING COMPANY, INC.

INSPECTION and TESTING of
Welding and Weldments
QUALIFICATION of
Procedures and Operators

Main Laboratories **Hoboken, N. J.**

Boston - Chicago - New York - Philadelphia - Providence

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Black and White **Effective October 2, 1950**

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Here's How To Assure Good Welding Fit-Up

Copyright, 1951, General Electric Company

SAVE TIME, POWER, ELECTRODES USE GOOD TECHNIQUES AND THE RIGHT ELECTRODE FOR THE JOB

Improper fit-up of joints to be metal arc-welded can slow production, waste man-power and electrodes, and increase costs at a tremendous rate. This is especially true of fillet welds on which the size of the fillet must be increased to compensate for poor fit-up if the joint is to have full strength.

TO ASSURE GOOD FIT-UP:

1. DESIGN JOINTS CAREFULLY—give careful consideration to the type and size of joints to be welded; simplify fit-up by eliminating irregular contours wherever possible.

2. ALLOW FOR DISTORTION—otherwise excessive gaps may appear in the fit-up of unwelded joints as assembly progresses.

3. CUT AND SHAPE PARTS ACCURATELY—inaccuracy which results from haste or the use of machines improperly adjusted or in need of maintenance is one of the greatest single causes of poor fit-up.

4. WELD IN PROPER SEQUENCE—weld least-contracting joints last, divide weldments into sub-assemblies, and weld outward from the center of a rigid structure.

To Assure Yourself of the Best in Electrodes:

Insist on G-E electrodes. They give you high deposition rates, meet AWS specifications, and are available in a wide variety of sizes and types.

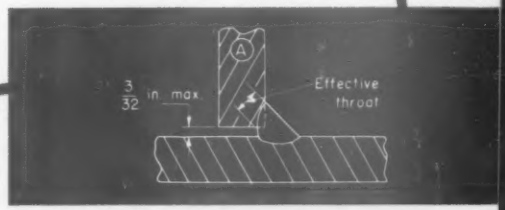
NEW! WELDING ELECTRODE SLIDE COMPARATOR

tells in an instant the AWS designation of manufacturer's electrodes.

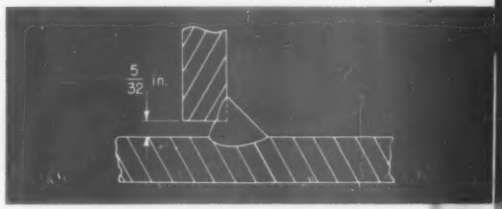
See your G-E Welding Distributor for your comparator. Look for General Electric under "Welding Equipment" in the yellow pages of your telephone directory. And remember, he carries a complete line of G-E welders, electrodes and accessories.

GENERAL ELECTRIC

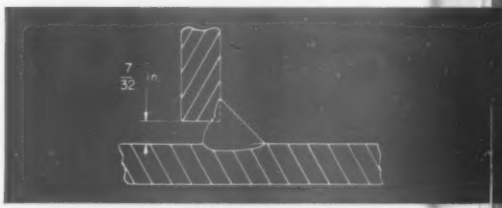
712-10



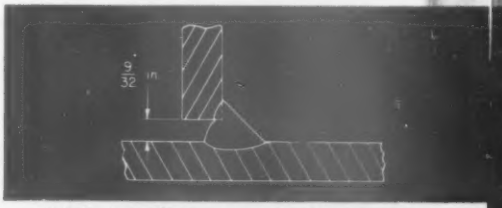
GOOD PRACTICE—Full throat size and strength are obtained when the fit-up gap is as much as 3/32 inches. The deposit penetrates the corner of Plate A as much as 3/32 inches. Larger gaps require excess welding.



WASTEFUL—With a 5/32-inch gap, a 3/8-inch fillet must be made to produce the strength of a 5/16-inch fillet. This requires approximately 50 per cent more time, power and electrode.



WASTEFUL—With a 7/32-inch gap, a 7/16-inch fillet must be made to produce the strength of a 5/16-inch fillet. This requires 100 per cent more time, power and electrode.



WASTEFUL—A 9/32-inch gap is a condition that ordinarily requires reassembling. If not refitted, it will require 200 per cent more time, power and electrode to produce the strength of a 5/16-inch fillet.

Another advantage of the new Fillerweld equipment, the engineers said, is the case with which operators can be trained to use it. In demonstrations, experienced arc or gas welders have learned to use the new welder successfully after only a few minutes of experimentation.

The new process can be applied to best advantage on stock less than $^3/_{16}$ in. thick. However, where speed is not of paramount consideration, Fillerweld will produce a high quality weld on thicker material. The equipment can be used with a G-E Type WP inert-arc welding transformer for welding aluminum, magnesium, or berylium copper; or with a G-E Type WD-4150 or WD-4200 for welding stainless steel, copper, Inconel, steel and other weldable alloys. Either argon or helium can be used with the equipment.

Stud-Welder Production Unit

New high-speed dual-head stud production unit has been developed by KSM Products, Inc., for military and civilian application. Unit combines precise fast operation and heavy-duty construction features. In operation, accurate placing of work in V holder is insured by built-in micro-switch which prevents operation if work is not correctly located. After loading suspension button and arc shield into each of the two welding heads and placing work in V holder, operator presses the two start buttons at front of unit. The unit then automatically completes the operation. Special features of the production unit include: automatic clamping device to prevent movement of work; leader-pin guides to insure accurate positioning of the work in relation to welding heads; and automatic spark shield which raises up in front of welding heads prior to welding to protect operator from possible flash or splatter. Capacity of the unit is eight welds per minute. For additional information, contact Engineering Dept., KSM Products, Inc., Merchantville, N. J.

DryRod Electrode Oven

Full protection against moisture absorption is promised users of mineral-coated electrodes by the Philip Roden Co., 1721 E. Lake Bluff Blvd., Milwaukee 11, Wis., manufacturers of the newly announced DryRod electrode oven. It is claimed the oven fills the gap between unpackaging of the manufacturer's sealed containers and actual use of the electrodes in the welding line. The DryRod electrode oven is a portable heated storage unit which provides control over the moisture content and temperature of electrodes at their point of use, and makes possible a system of orderly electrode control whereby assurance of better quality welds may be had.

According to the manufacturer, the DryRod will accurately control the moisture to within 0.2%, the normal accepted U. S. Government standard for moisture content. The oven is basically a cylindrical, compartmented sheet-metal unit which is heated by an 840-watt element operating off 110- or 220-v. circuits. Fully insulated, it has a low heat loss which adds to its efficiency. An important feature is the variable thermostat which gives close control on temperatures up to 600° F. Dimensions are 22 in. O.D. by $25^1/_2$ in. long, with a capacity of 350 lb. of electrodes up to 18 in. in length. Shipping weight is 112 lb.

Cable Connector

Cam-Lok, a division of Empire Products Inc., Cincinnati, Ohio, has just announced a new and improved Cam-Lok welding cable connector. The connector is made of solid brass perfectly machined to a smooth sliding fit. The design consists of a double-cam principle where one cam exerts pressure parallel to the axis of the connector, the other perpendicular to the axis. Contact approaching the 600 lb. per sq. in. needed for minimum resistance is obtained. General-purpose Cam-Lik connectors (for 1/0 through 3/0 cable and No. 2 through 1/0 whip ends) are completely interchangeable with heavy-duty Cam-Lok connectors and with general-purpose and heavy-duty female terminal connectors. Long runs of cable can be graduated from 4/0 down to a light whip end for maximum flexibility and minimum voltage drop. No adapters or reducers are needed. The Cam-Lok connector is self-compensating for wear, locks tight, releases easily, has no spring action, and reduces arcing and burning to a minimum. For further details write for technical bulletin No. 101, W-63.

Gasoline Cutting Torch

A revolutionary cutting torch was demonstrated recently at the American Steel & Wire Co. junk yard at Worcester, Mass. James A. Browning, the inventor, is an instructor at Dartmouth College. The torch uses gasoline instead of acetylene. The oxygen is turned on first, then the gasoline. This is the only difference from operating other torches using gaseous fuels. The oxygen carries atomized gasoline to the torch nozzle

James A. Browning demonstrating his gasoline fired cutting torch on a 1 in. thick section of the boiler of a steam locomotive, being cut up for scrap in the yards of the American Steel & Wire Co.

(which also serves as a heat exchanger) where a uniform mixture of gasoline, vapor and oxygen is formed. This mixture is ignited to produce the preheating flame. About 10 sec. is needed to form the required flame when the torch is started from a cold condition. Thereafter, the flame is obtainable immediately.

"Back-flash" of the flame into the torch body is eliminated with the Browning Cutting Torch. Only 20 lb. pressure is made. When not in use, the pressure may be completely released. If the gas line should be cut, and pressure lost, safety valve in the tank shuts it off.

NEWS OF THE INDUSTRY

Plant Maintenance Conference at Philadelphia in January

Plans for the third Plant Maintenance Conference, to be held concurrently with the Plant Maintenance Show at Convention Hall, Philadelphia, Jan. 14–17, 1952, call for the most intensive examination of maintenance problems ever undertaken, it was announced by Clapp & Poliak, Inc., the exposition management.

Thirty-four separate discussions will be conducted. More than 100 experts, drawn from industrial firms all over the country, will lead the panels. Ten thousand maintenance executives are expected at the show and conference. L. C. Morrow, consulting editor, Factory Management & Maintenance, is chairman.

Six general conferences, 27 sectional meetings and the annual banquet are scheduled. General conferences will consider basic problems of all industry while the sectional meetings will be devoted to specialized subjects of interest to particular industries.

On the last day of the conference, 16 round-table groups will meet. Topics include organization of personnel; maintenance operating policies; safety and plant protection; plant housekeeping; welding; maintenance of mechanical equipment; maintenance of power plants and service equipment, and maintenance applications of handling equipment and its upkeep. Also included are sessions devoted to maintenance in aircraft plants; food plants; glass plants; oil refineries, printing plants; pulp and paper plants; textile plants and woodworking plants.

Two hundred companies will display products and services necessary for maintenance. Both conference sessions and exhibits will place the principal stress on preventive maintenance. The exhibit area will cover four times that of the first show.

Advance registration cards and hotel information may be obtained from Clapp & Poliak, Inc., 341 Madison Ave., New York 17, N. Y.

A.S.T.M. 50th Anniversary Meeting

To arrange and carry out a number of special events for the 50th Anniversary Meeting of the American Society for Testing Materials—to be held in New York City at the Hotels Statler and New Yorker during the week of June 23, 1952—a General Committee on Arrangements has been appointed, headed by A.S.T.M. Past-President J. R. Townsend, Materials Engineer, Bell Telephone Laboratories. Associated with Mr. Townsend are upwards of 75 active members and officers.

At the organization meeting in September, announcement was made that numerous special symposiums were being developed as part of the technical program. In all, some 35 sessions will be necessary to take care of the large number of papers and reports.

It is expected there will be groups of papers and symposiums on the following subjects: fretting corrosion; synthetic fibers; adhesives; direct shear test of soil; exchange phenomena in soils; continuous analysis of water; plastics; conditioning and weathering; methods for determining elastic constants; light microscopy; fatigue; effect of temperature; tin.

The Lincoln Electric Co. Moves Into New Plant

Monday morning, September 17th, was M-day for the office workers of The Lincoln Electric Co., Cleveland, Ohio. Over the preceding week end all executive and plant offices with their equipment were moved to Lincoln's new supermodern plant which has been described by Peter Greenough, industrial writer, as the "most extraordinary temple of industry in America." The company's headquarters are now at 22801 St. Clair Ave., Cleveland 17, Ohio.

The office move over the week end was but one step in the transferring of Lincoln's operations without losing any more than 10% of production for the month during which the complete move was made.

Pin-point planning made the move a smooth operation, with production on each machine picking up at the new plant a few hours after stopping at the old. Raw material was moved out first while machines at the old plant were kept operating on the month's work which was in process. The basic machines, shears and presses, ran out of work first and they were moved to the new location where they began to work on the raw material previously stocked there. As material was processed through the old plant and machines ran dry they were moved out to begin on the raw material which had been started in process by the first machines moved out. Operators went along with their machines which were quickly set into marked locations and hooked into the power lines. At the end of the third week practically all of the material in the old plant had been processed and assembled into welders. The assembly lines were then moved to the new location where parts were now ready for assembly. The move of the company's machine division, now complete, has involved tons of material and some 1500 machines. Work has begun on moving out the electrode division which will complete the transfer of all operations into the new plant.

Eutectic $2000 1951 Welding Prize Competition

A grand total of $2000 in cash awards, double that of the previous year, plus a considerably increased scope of the competition to include practical welding applications, marks the announcement of its 1951–52 Prize Competition and Program of Awards released by Eutectic Welding Alloys Corp. of Flushing, N. Y.

This year's competition, open to engineers, metallurgists, researchers, instructors, welders, students and all others qualified, features two categories: Category A—for papers on "Welding Engineering & Theory"; Category B—for papers on "Practical Welding Applications." Both divisions must cover technological and research aspects, procedures and applications of the use of lower melting (lower than parent) filler metals in the nonfusion welding processes.

A total of thirty cash prizes will be awarded in the various categories described above, the first prize (won last year by two Georgia Tech. students) being $500.

A full set of rules, entry blanks and helpful suggestions on the preparation of papers may be obtained by writing Eutectic Welding Alloys Corp., Dept. P, 172nd St. and Northern Blvd., Flushing, N. Y.

Cunningham Equipment Appointed Distributor

The J. A. Cunningham Equipment, Inc., members of the SOCIETY, have been appointed a distributor for Osborn Wire Brushes in Eastern Pennsylvania, Southern New Jersey and Delaware.

All-State Doubles Space

John C. Bailey, Managing Director, Civic and Business Federation, White Plains Chamber of Commerce, White Plains, N. Y., announced today the unanimous Board approval of a resolution introduced by the Federation president, Charles J. Goyert, memorializing All-State Welding Alloys Co., Inc., on the opening of its doubled factory area in this city.

The new structure adjoins All-State's home office and plant on Ferris Ave., White Plains, and more than doubles their factory area. It houses modern equipment for extruding, flux coating, cleaning, straightening, cutting, drying and packaging as required by the rapidly expanding demand for All-State products. In addition it provides expanded laboratory and engineering facilities for All-State's Technical Div. serving the needs of All-State distributors everywhere.

American Welding Expands

Plans for additions to plant and equipment of The American Welding & Manufacturing Co., Warren, to cost in excess of $5,000,000, were announced today by William J. Sampson, Jr., president.

"The expansion," he said, "will permit American Welding to increase substantially its production of urgently needed jet- and reciprocating-aircraft-engine parts.

"Our already sizable backlog of this type of defense work," Sampson said, "got another boost only a few days ago when we received over $3,000,000 in new orders for such items as coated nozzle boxes, turbine casings, exhaust cones and many stainless steel and titanium welded ring applications."

Sampson estimated that about 20,000 sq. ft. of the new addition, complete with all new facilities, should be in operation soon after the first of the coming year.

Among the companies for which American Welding now produces vital engine components are: General Electric, Allison Div. of General Motors Corp., Westinghouse, Pratt & Whitney, Wright Aeronautical, Solar Aircraft, Ryan Aeronautical, Rohr Aircraft, Thompson Products, Studebaker, Convair, Glenn L. Martin, Heintz Manufacturing, Fairchild and Budd.

At the recent National Air Races in Detroit, rings and components manufactured by American Welding were in some of the engines that set new speed records.

Farm Welding Awards

The results of the first nation-wide arc-welding award program for agricultural high-school students have been announced by The James F. Lincoln Arc Welding Foundation of Cleveland, Ohio. If the list of winners is typical of what high-school students are doing throughout this country, farmers and ranchers do not have to worry too much about their machinery and equipment if they have a boy in the shop mechanics course at high school.

The 100 awards, ranging from $600 to $25, were given to high-school students in 31 different states for the best descriptions of farm-welding projects. In honor of the first 10 main award winners the schools in which they were enrolled received duplicate awards to be used as funds for the improvement of shop mechanics courses.

Stand Reifel of Ontario, Calif., because his father had to move horses into town, decided to make a horse trailer. His description of how he made a trailer worth $1000 as a school project, for only $305 won him First Award of $600. His school, Chaffey Union High School, also received $600.

Because roping cattle for branding and treating was slow and tedious work, Raymond Lubracherie, San José, Calif., made a cattle squeeze. His description won Second Award of $400 and his school, Live Oak Union High School, received an equal award.

Both Jack Seitzinger, Vincennes, Ind., and Ronald Pourroy, San Martin, Calif., had the problem of moving machinery about scattered acreage and along highways. They both made machinery trailers, and described them to each win one of the two Third Awards of $200. Lawrenceville Township High School and Live Oak Union High School each received $200 for their shop mechanics courses.

The Foundation states that it is sponsoring this program at this time because of the critical machinery and help problems facing farmers. The purpose is to encourage farm boys to study, by using welding, how they can become more self-sufficient in their farming operations and how they can increase farm production by making and using time and labor saving devices. The projects described were generally something that eliminated hard work at home such as trailers, carts, wagons, diggers, mixers, saws, feeders and loaders.

Papers were judged by a Jury of Award composed of Dr. E. E. Dreese, Chairman of the Dept. of Electrical Engineering at Ohio State University, O. E. Kiser, State Supervisor of Agricultural Education, New Jersey, A. H. Hollenberg, Specialist in Farm Mechanics, U. S. Office of Education and Ray Morrison, Vo-Ag teacher, Clay Center, Kan.

LIL CHAMP
WOW- IS THAT ROD FAST!!!
BOY, THESE CARS ARE SURE COMING THROUGH FAST NOW THAT THEY BOOSTED PRODUCTION IN SUB-ASSEMBLY
EVER SINCE WE SWITCHED TO CHAMPION GRAY-DAC OUR PROBLEMS WITH POOR FIT HAVE VANISHED !!
WHAT A ROD! THAT CHAMPION GRAY-DAC REALLY FILLS THE BILL FOR FAST FILLETS— HANDLES SWEET AS HONEY GOES IN AS HOT ROD BUT FILLS GAPS AND DOESN'T BURN THROUGH- TAKES PLENTY OF HEAT AND YOU CAN BURN IT DOWN RIGHT TO THE END !!!
GIT HIM !! EVERY WELDER SINGS THE PRAISES OF CHAMPION GRAY-DAC AS SOON AS HE BURNS HIS FIRST STICK—
CHAMPION GRAY DAC AWS E-6013
THE CHAMPION RIVET CO.
CLEVELAND, OHIO East Chicago, Ind

NEW DryRod Electrode Oven

stops moisture pickup in low-hydrogen electrodes

Problem: Unprotected low hydrogen-ferritic electrodes absorb hydrogen-generating moisture

Solution: DryRod, required equipment, controls moisture content to approved standard of .2%

First in the field and *proven in use* by leading fabricators throughout the country, DryRod solves the problem of moisture pickup in mineral-coated electrodes. DryRod, developed with the assistance of major electrode manufacturers, preserves original "baked-in" quality by automatically controlled temperatures to 550° F . . . always keeps electrodes at highest efficiency. This means better quality welds . . . less rework, less scrap . . . *lower cost per weld.* Be sure to write for all the facts TODAY.

Ask for a demonstration

DryRod *gives you all these features*

- Electric tubular heaters—plugs into 110-220V line
- Adjustable temperature control 200-550°F—equal heat distribution
- Insulated—low heat loss
- Capacity—350 lbs.
- Vented—adjustable regulator
- Removable perforated shelves
- Sturdy, all-welded flanged heads
- Light weight, only 102 lbs.

Philip Roden Co.

1723 E. Lake Bluff Blvd. MILWAUKEE 11, WIS.

NEW LITERATURE

Mixing Gases

A special booklet for students and those interested in knowing how a welding torch works entitled "You Don't Need an Egg Beater to Mix Gases" has been published by National Welding Equipment Co., 218 Fremont St., San Francisco 5, Calif. Copy available on request.

Twecolog

A new 12-page, No. 8 Twecolog illustrates and describes the complete line of Tweco electrode holders, ground clamps, cable connectors, terminal connectors, cable splicers, mechanical and solder-type cable lugs, carbon electrode holders and the new "lug-set" block and punch for attaching solder-type lugs to cables without solder. Contains information about the care and maintenance of electric welding cables and connections. Mailed free to those using the electric welding process. Tweco Products Co., P.O. Box 666, Wichita, Kans.

Free Aid to Better Arc Welds

A pocket-size booklet "Hobart Welding Electrodes and Welders' Vest Pocket Guide," containing useful arc-welding information, is now available free from Hobart Brothers Co., Troy, Ohio. This handy booklet gives information on metals and electrodes, types of electrodes, four essentials of proper welding procedures, color marking for identification of electrodes, types of joints, typical positions, standard steel shapes, characteristics of the fillet weld, causes of common welding troubles, average electrode consumption, handy reference information, and complete information and instructions for using all Hobart electrodes. Send for your free copy to Hobart Brothers Co., Box EW-1618, Troy, Ohio.

Welding-Alloys Chart Issued by Eutectic

A handy new chart of Eutectic low-temperature welding alloys, measuring 10- x 14-in., suitable for wall hanging or for purchasing-department files, has been issued by Eutectic Welding Alloys Corp.

The new chart contains detailed specifications on close to 200 metal-joining alloys including bonding temperatures, tensile strengths, recommended uses, etc.

Major listings show proper welding alloys for use with cast iron, steel, stainless steels, copper, brass, bronze, nickel and nickel alloys, aluminum and aluminum alloys, magnesium alloys and zinc die castings as well as for hard overlaying cutting, chamfering, piercing, gouging and joint preparation of all metals.

Further subdivision of the information covers the use of the alloys with various heating methods, i.e., torch, arc and inert-gas-shielded-arc welding.

Copies of this chart may be obtained free upon request by writing to Eutectic Welding Alloys Corp., Dept. P, 172nd St. and Northern Blvd., Flushing, N. Y.

Fusion Welding of Nickel and High-Nickel Alloys

A new, 44-page booklet on the fusion welding of nickel and the high-nickel alloys has just been published by The International Nickel Co., Inc. It contains 44 pages and includes more than 30 tables and almost 50 drawings and photographic illustrations.

A complete technical treatise on the subject, it covers various forms of electric-arc welding as well as gas welding. There are over 20 chapters and sections covering, in addition to detailed welding instructions, such information of importance to production and welding engineers as the boiler code of the American Society of Mechanical Engineers, pickling, testing and inspection safety methods and associated topics.

The booklet, designated as Technical Bulletin T-2, is available without charge through the Technical Service Section of The International Nickel Co., 67 Wall St., New York 5, N. Y.

Data Offered on High-Temperature Problems

The Development and Research Div. of The International Nickel Co., Inc., is offering data from its files on high-temperature applications of metals and alloys. These files cover service records and results of plant and laboratory tests. They are not limited to nickel alloys but include quantitative data on many other materials, both wrought and cast.

The Division has prepared a work sheet, or questionnaire, designed to facilitate inquiries on specific high-temperature problems to which answers may be found in these files.

The offer of this work sheet is especially directed to metal users who:

1. Are undertaking a new process with which they have not had operating experience, involving possibilities of corrosion at high temperature.
2. Desire to compare the performance to be expected from other metals and alloys with that of materials previously used and found satisfactory.
3. Require a substitute for an alloy or material at present not readily available.

The work sheet is obtainable through the Development and Research Div., The International Nickel Co., Inc., 67 Wall St., New York 5, N. Y.

Bulletin—Copper in Stainless Steels

In recent years a considerable number of copper-bearing stainless steel alloys have been developed and are now being commercially produced. Many of these special stainless steels are now extensively used in many applications which require alloys of high corrosion resistance or alloys exhibiting age-hardening properties.

The bulletin discusses in detail the physical, metallurgical and welding properties of many experimental and commercial copper-bearing stainless steels containing up to 30% chromium and between 0 and 35% nickel. The copper additions in most of the discussed alloys usually varied between 1 and 5%.

Among the topics covered are the phase relations, hot-working properties, corrosion resistance, age-hardening characteristics, effects of alloying elements such as Mn, Si, Mo, Cb, Ti, W, Be, V, stress-corrosion cracking, heat treatments, mechanical properties and weldability. In addition, detailed tables are given in which the various American and foreign patented and commercial alloys are listed.

The report represents a compendium of 166 references representing published articles as well as many unpublished contributions received from various research investigators in the United States and abroad.

This bulletin (No. 9) is now on sale by the AMERICAN WELDING SOCIETY, 33 W. 39th St., New York 18, N. Y., at $1.00 per copy.

Metal-Cleaning Guide

Oakite Products, Inc., manufacturers of industrial cleaning and related materials, announce the publication of a new edition of the 44-page illustrated booklet, "Some Good Things to Know About Metal Cleaning," reviewing metal cleaning in all its many phases.

The booklet discusses the wide variety of soils resulting from such metal-fabricating processes as heat treating, forging, rolling, stamping, drawing, extruding, spinning, grinding, machining, buffing, etc., then describes specific materials, equipment and procedures for the removal of these soils. Among the many metal-cleaning and related operations reviewed in detail by the booklet are the following: tank-cleaning methods; machine-cleaning methods; electrocleaning steel; electrocleaning nonferrous metals; pickling, deoxidizing, bright dipping; prepaint treatment in machines; prepaint treatment in tanks; paint-stripping; steam-detergent cleaning; barrel cleaning, burnishing; cleaning in hard-water areas; treating water in paint-spray booths; rust-prevention procedures; machining and grinding.

Readers desiring free copies of this metal-cleaning booklet may obtain them by addressing Oakite Products, Inc., 118E Thames St., New York 6, N. Y.

LIST OF NEW MEMBERS

September 1 to September 30, 1951

ANTHONY WAYNE

Fowler, Franklin S. (B)

BIRMINGHAM

Hamm, E. Paul (C)
Hill, Taylor (C)
Potts, W. B. (C)

BOSTON

Avery, Shailer (B)
Cummings, John Leo (B)
Goldman, Joseph (B)
Saul, Arthur D., Jr. (B)
Twomey, John C. (C)
Yelverton, Charles D. (C)

CHICAGO

Barron, William M. (C)
Bergmann, Walter G. (C)
Fabert, Herman A., Jr. (B)
Gaedtke, R. V. (C)
La Pota, John (C)
Miller, P. E. (C)
Olson, J. F. (C)
Palmer, Paul E. (B)
Ridenour, Charles E. (C)
Spencer, Edward P. (C)
Strandwitz, Norman S. (C)
Surane, Joseph E. (C)
Thurston, Robert T. (C)
Tylutki, M. A. (C)
Ward, Bert G., Jr. (C)

CINCINNATI

Kling, Jack J. (B)

CLEVELAND

Berneike, Elmore G. (B)
Dempsey, William F. (C)
Gerould, David S. (C)
Hennie, Ralph, Jr. (C)
Kells, Thomas G. (C)
Mazurek, Henry P. (C)

COLORADO

Browning, Edward O. (C)
Donmyer, Philip (C)

COLUMBUS

Henkin, J. H. (C)
West, L. M. (C)

DALLAS

Gammon, Glenn (B)

DETROIT

Carey, Thomas J. (B)
Coltson, Stanley A. (A)
Folmer, Frank (B)
Geralds, Gerard (B)
Haley, Thomas A. (B)
Jacques, Charles F. (B)
Liska, James (B)
Manduch, Frank J. (B)
Milton, Bond (C)
Slack, Kenneth (C)
Steger, Robert C. (B)
Tatham, C. H. (B)

HARTFORD

Ebersold, William T. (B)
Gamache, Rodolphe W. (C)
Morrone, James J. (C)
Sullivan, John F. (C)

HOUSTON

Walser, Curtis L. (B)

INDIANA

Terry, Roland A. (C)
Trussel, Jack B. (C)

KANSAS CITY

Broderson, Dean E. (C)
Rimmer, Norman W. (B)
Worcester, Kenneth E. (C)

LEHIGH VALLEY

Moyer, Robert E., Jr. (B)

LONG BEACH

Walling, Albert Shell (C)

LOS ANGELES

Burke, Walter (B)
Cox, M. A. (C)
Eichman, Orville A. (B)
Weightman, Herbert G. (B)

LOUISVILLE

Bentley, F. G. (B)
Hicks, Bill (C)
Keith, Emmett (B)
Keith, Leon (B)
Preston, Walter (B)

MAHONING VALLEY

Flasch, Raymond (B)

MARYLAND

Coulter, W. V., Jr. (C)
Johnson, A. R. (C)
Kaminski, John P. (C)
Leary, E. G. (C)
Lee, Francis M. (C)
McAfee, Thomas W. (C)
Miedzianowski, Melvin (C)
Rairigh, W. Wayne (C)
Shook, Melvin J. (C)
Zopfi, H. E. (C)

NASHVILLE

Holland, R. S. (B)
Miller, G. H. (B)

NEW JERSEY

Buckley, Dan (B)
Moen, Walter B. (C)
Warshal, Morris (B)

NEW YORK

Andrasko, John, Jr. (B)
Menson, John L. (A)
Vanderman, E. J. (A)

NIAGARA FRONTIER

Helmbrecht, John J. (B)
Manley, J. S. (B)
Mohney, A. W. (C)
Myers, Arthur E. (C)
Roemer, Raymond B. (C)
Smith, Ray (B)
Stevens, Robert P. (C)
Thornburg, Sterling (B)
Wagner, Robert J. (B)

NORTHERN NEW YORK

Beirne, William A., Jr. (C)
Domina, Frederick H. (D)
Ellis, J. R. (C)
Gowen, John A. (C)

NORTHWEST

Anderson, H. A. (C)
Collom, Merton P., Jr. (B)
Cottrell, Richard G. (B)
Davies, George J. (C)
Markwell, John W. (C)

OKLAHOMA CITY

Enochs, Elmer P. (C)

PEORIA

Cadwell, W. C. (C)
Kimsey, W. P. (C)
Merriman, James F. (C)
Russell, Everett V. (C)

PHILADELPHIA

Stone, James E., Jr. (B)

PITTSBURGH

Adamson, Ralston G. (B)
Blackstock, William H. (C)
Cox, A. M. (B)
Cox, Elmer J. (B)
Cox, G. Robert (C)
Hlivka, Andrew (C)
Meyers, Joseph A. (C)
Minnick, E. J. (C)
Morgan, George (C)
Murray, John M. (C)
Smith, Charles A. (C)
Tomec, Jack W. (C)

PORTLAND

Belieu, Joseph R. (B)
Berry, Russell (B)

PUGET SOUND

Allan, Douglas M. (B)
Bryant, Bruce G. (B)
Howe, Hubert S., Jr. (C)
Lindahl, C. A. (B)
Pfaff, William C. (B)

RICHMOND

Cobb, A. L. (B)
Gorrie, John M. (B)

ROCHESTER

Noser, Robert (C)

SAGINAW VALLEY

Williams, W. F. (C)

ST. LOUIS

Bedard, L. A. (B)
Howery, James A. (C)
Kolnik, John P. (B)
Rothweiler, R. C. (C)

SALT LAKE CITY

Hansen, Peter Stenberg (B)
Thomas, Fred S. (B)
Tueller, Loyd (B)
Zaccaria, Frank (B)

SAN FRANCISCO

Grant, H. C. (B)
Pal-Freeman H. E. (B)
Scudder, Howard Lester (B)
Wilcsinczky, Carl (B)

SYRACUSE

Helmer, Jack N. (C)

TRI-STATE

Blackburn, William B. (C)
McDonald, J. B. (C)
Richardson, W. Frank III (C)
Schmitt, W. E. (B)
Snyder, Howard A. (C)
Weaver, Charles (C)

WASHINGTON

Burnside, Robert (B)

WESTERN MICHIGAN

Fletcher, Fleming D. (B)
Girod, Jesse C. (B)

WICHITA

Rutledge, Walter A. (C)

WORCESTER

Carlson, Ernest J. (B)
Geoghegan, J. Edward (B)
Howarth, Clarence E. (C)
Jackson, Robert V. (B)

YORK-CENTRAL PA.

Greenwood, Kelton H. (B)
Martin, J. Edward (C)
Neitz, Earl F. (B)

NOT IN SECTIONS

Hayward, C. J. (B)
Hillistad, Richard G. (C)
Hopkins, Howard E. (C)
Knight, George A. (B)
Koning, C., Jr. (C)
Oliver, Norman J. (B)
Taylor, L. J. (B)

Members Reclassified

During the month of September

CHICAGO

Monk, Carl W. (C to B)

CLEVELAND

Gibson, A. E. (A to F)
Hodge, J. C. (B to A)
Sipe, Ray C. (C to B)

COLUMBUS

Zampfer, Roger A. (D to B)

DETROIT

Tromans, Harold (C to B)
Zanichelli, Joseph M. (C to B)

NEW YORK
Weigel, A. C. (A to F)

NIAGARA FRONTIER
Gehring, R. P. (C to B)

NORTHWESTERN PENNSYLVANIA
Huston, Robert J., Jr. (C to B)

PHILADELPHIA
Bonowitz, Michael J. (C to B)
Bradway, Ralph D. (C to B)

PITTSBURGH
Kiggins, W. Ralph (C to B)

ST. LOUIS
Johnson, O. Knox (C to B)

WORCESTER
Caranchini, U. S. N. (C to B)

SECTION ACTIVITIES

prepared by C. M. O'Leary

Anthony Wayne

The first meeting of the 1951–52 season of the Anthony Wayne Section was held at Indiana Technical College, Friday, September 21st. Professor Robert C. Ruhl, Dean of Indiana Tech was Chairman.

It was called "Indiana Tech Night." Harry M. Johnson, A.W.S. Chairman, welcomed members, students and guests, and gave a brief history of welding, the need for it and its benefits.

George H. Laws from Ruckman-Hansen, Inc., talked on design, lower costs, savings of steel and other points on structural steel welding. His talk was illustrated with slides on structural work and bridges.

Harold Hamilton of International Harvester Co. spoke on the importance of welding.

Through the courtesy of the Anaconda Copper Co., a sound technicolor movie "Copper, Mining, Smelting and Refining," was shown and enjoyed by all.

A short discussion period followed. Attendance at the meeting was 62.

Arizona

The Arizona Section held its first meeting of the winter season on Wednesday, September 19th, as guests of the Arizona Brewing Co., Phoenix. After being served refreshments and lunch by the Arizona Brewing Co., the members were escorted on a tour through the brewery. The group had an excellent opportunity to observe welding applications in structural steel and very wonderful applications of brazing copper. The huge copper vats were all welded bringing about structures which would be impossible to obtain by any other method. Upon completion of the tour, the members were well aware of the important part welding plays in today's construction of equipment and machinery.

Approximately thirty-five members were present at the meeting which began at 7:30 P.M. and adjourned at 10:00 P.M.

Bridgeport

The Bridgeport Section held its September dinner meeting on the 20th at Rapp's Restaurant, Shelton, Conn.

James Dehn of Ryerson Steel gave an extemporaneous, semi-technical talk on Stainless Steels and Their Uses. Mr. Dehn's talk covered new information on the subject.

A short talk was given by *Chairman* G. F. Mulligan, Jr., on the coming programs for the season. *Membership Chairman* Austin A. Young gave a short talk on his membership plans. *Treasurer* R. A. Lalli gave the facts and figures on the financial status. *Secretary* William A. Seymour gave a short talk encouraging every member to bring in a new member. *Technical Chairman* J. R. Skibo advised all members that it is his purpose to help them with their technical problems and invited them to use this service.

Chattanooga

The first meeting of the season of the Chattanooga Section was held at the Chattanooga Rod and Gun Club, September 7th.

It was a strictly social gathering in the form of a fish fry.

Everything went smoothly and all present appeared to have a very good time.

Several prospective members were present and introduced to the gathering.

Colorado

Dinner meeting of the Colorado Section was held on September 11th at the Oxford Hotel, Denver.

A. B. Tesman of the Tempil Corp., presented an excellent technical talk on Preheating for Welding. Mr. Tesman used slides to illustrate his talk.

Dallas

A joint meeting was held with the American Society for Metals on September 19th in the Banquet Room of the Venus Restaurant.

L. D. Richardson of the Eutectic Welding Alloys Corp. presented an interesting, clear-cut talk on The Use of Non-fusion Filler Metals on Tools and Dies. A film "The Eutectic Story" was also shown and viewed with interest.

A symposium on Spot Welding of Aluminum Alloys in Aircraft Construction was held at the Chance Vought Aircraft Plant, Grand Prairie, Tex. on September 20th and 21st. The symposium was sponsored by the Dallas Section, with the Chance Vought Aircraft as co-sponsor and host.

Delegates from all of the aircraft manufacturing plants in the Southwest convened for this two-day symposium.

The meeting was divided into four sessions, two each day, and the discussions covered the procedures, controls and equipment used by the various manufacturers in assembling airframes by this process, and means for improving and speeding up the same for the benefit of the defense effort. Approximately fifty persons attended each session.

Also present and taking part was G. N. Sieger, President of S.M.S. Corp. of Detroit, and a Past-President of the AMERICAN WELDING SOCIETY; and Julius

Symposium on Spotwelding Aluminum Alloys—Dallas Section

Heuschkel of the Westinghouse Electric Corp. Research Laboratory at East Pittsburgh, Pa. Mr. Heuschkel is Chairman of the Resistance Welding Committee of the A.W.S.

The Thursday morning session covered Specifications and Inspection and was presided over by G. L. Lord of the Process Control Group of Chance Vought. The Thursday afternoon session covered Welding Schedules and Techniques and the Session Chairman was Mr. Heuschkel.

The Friday morning session was entitled "Work Surface Preparation Tip Pick-Up and Electrode Tips," and the Chairman was A. W. Graves, Supervisor of Process Control Group at Chance Vought. Friday afternoon's session discussed Welding Machines, Instrumentation and Training of Personnel. Mr. Sieger presided at this session.

Interest was high and discussion lively throughout the four sessions and the unanimous opinion was that much beneficial information was exchanged and real progress made toward the over-all objective. Hope was expressed by many that further meetings of a similar nature would be held in the near future. A condensed brochure of the proceedings is in preparation.

Hartford

Dinner meeting of the Hartford Section was held on Wednesday, September 12th, at the Rockledge Country Club, West Hartford.

One of the speakers was Kenneth L. Mytinger of the U. S. Department of Commerce, Field Operations. His experience with the War Production Board during World War II qualified him to speak on the Conservation of Materials in the Present War Effort.

The other speaker was Capt. William L. Schatzman, of the Connecticut State Police. He is Chief of Security, Office of Civil Defense of the State of Connecticut, and he spoke on the highly important subject of Civil Defense. His talk was illustrated by a sound movie film entitled, "Tale of Two Cities."

Houston

The initial meeting of the Houston Section for the 1951–52 season was held September 20th at the Houston University.

The subject of the meeting, "Graphitization of Carbon Steel at Elevated Temperatures" was of extreme interest as testified by the attendance and attention paid the speaker. The speaker, John S. Cook, Chief of the Inspection Department, Humble Oil and Refining Co., Baytown, Tex., is a member and a director of the Houston Section.

This was one of the largest meetings held by the Section with an attendance of 134 members and guests.

The meeting, as usual, began with an entertainment program which consisted of a sound color movie sponsored by the Humble Oil and Refining Co., entitled "High Lights of the Southwestern Conference of 1950."

After an excellent steak dinner, the speaker was introduced by *Section Chairman* Sam C. Hamilton. Mr. Cook told the audience that one of the most serious problems being encountered by his department at the big Baytown refinery is the graphitization that has taken place in one of the larger reactors. After this reactor has been in service for several years at elevated temperatures it was found to be cracking throughout the plate and alongside the welds. Mr. Cook showed slides and micrographs picturing the vessel and points of failure. He described their interpretations of the causes of failure plus the action that they are taking to prevent future failures due to graphitization of similar carbon-steel reactors. All members were pleased when it was pointed out that one of the few places where no cracks were observed was in the welded seams. After completing his talk, Mr. Cook answered many varied and interesting questions.

The Houston Section will do its best to see that future meetings scheduled for the remainder of the year will be as well received as this initial meeting. The Section has scheduled ten meetings for the year, including two social meetings, one at Christmas and one in June; also a plant visit through the Hughes Tool Co. plant, and a symposium for design, fabrication, inspection and erection of welded steel buildings will be held next spring.

The Houston Section is pressing to extend their membership and it is hoped to surpass the record of last year when there was an increase of 57 new members. The Section challenges any and all Sections to equal the record which they plan to set this season.

Indiana

An attendance of 215 was present at the dinner and meeting held on September 28th at the Allison Div., G.M.C. Restaurant, Indianapolis, Plant No. 5. Bob Beckman of the Allison Div., welcomed the members and spoke to them on the history of Allison.

Speaker at the meeting was P. G. Parks, Welding Engineer, Solar Aircraft Co., Des Moines, Iowa. His subject "How Jet Engines Are Welded" was followed by a question-and-answer session. A film "Harnessed Lightning" was shown through the courtesy of Allison. A cutaway model each of an axial-flow type and a centrifugal type jet engine were on display for detailed examination.

Louisville

The first meeting of the new season was held on September 25th with H. L. Sittler, Metallurgist of the Arcrods Corp., Sparrows Point, Md., as speaker. Mr. Sittler's subject, Low-Hydrogen Electrodes" dealt with the development, uses and advantages of this new type of electrode. The membership was particularly interested in the use of this rod to help eliminate under-bead cracking in low-alloy welds. The fact that this rod also produces a weld having a high resistance to impact at low temperatures was of considerable interest.

It was decided that for this coming year a buffet dinner would be served in place of the present Dutch lunch.

Michiana

The Michiana Section opened the current season of local activity on September 20th with a discussion of "Unique Applications of Oxygen." H. T. Smith, Development Engineer for The Linde Air Products Co. was the speaker. The talk was illustrated with slides and movies.

Three applications were described. To some, the most unique was the use of an oxy-fuel oil flame plus water spray to substitute for a mechanical drill in boring blasting holes in taconite ores. The minerals involved are very hard causing drills to penetrate slowly and wear rapidly. The present device uses the expansion-contraction differentials of rock to spall particles from the face and sides of the holes by heating with the flame then spraying with water. The ensuing steam plus products of combustion, escaping out the back end of the holes, carry the rock debris out, thus exposing a new surface to the attack of heat and water. Penetrations several times that of conventional drills can be obtained in a given time.

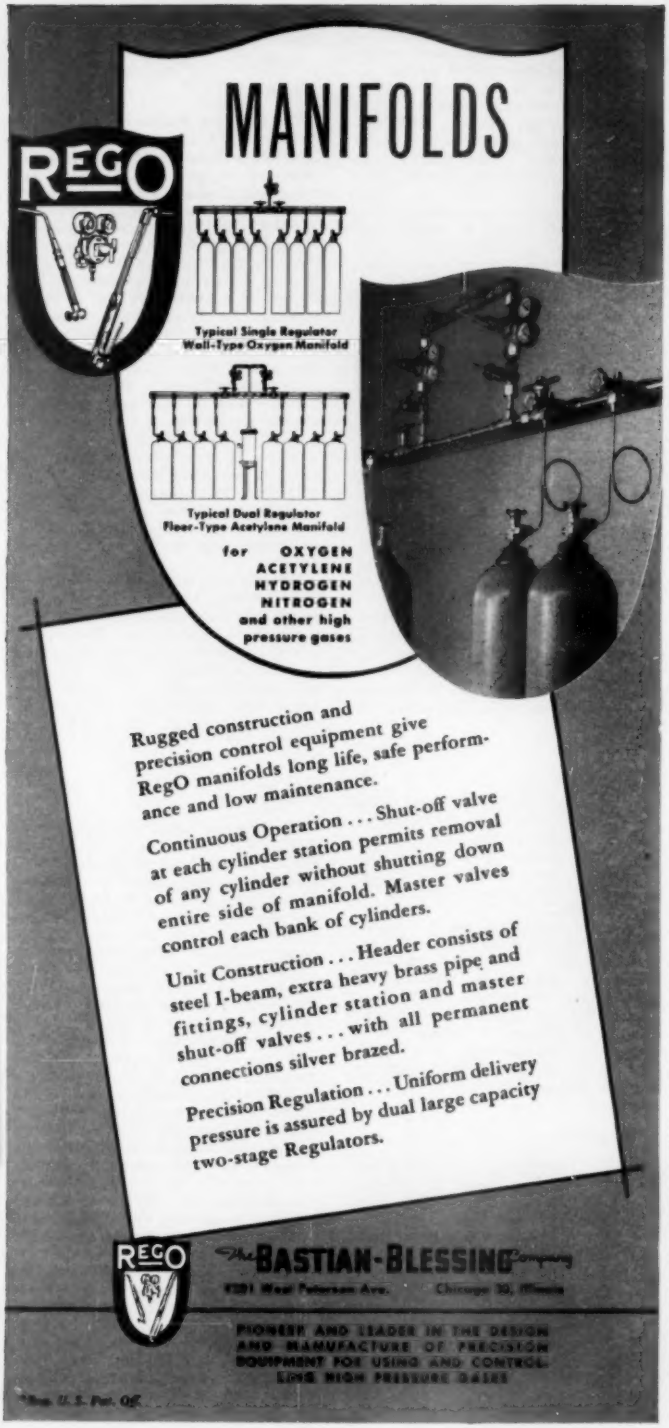
The other two applications are steel-mill developments. One is the use of oxygen to speed the refinement of steel by bubbling it through the molten bath. This method of introducing oxygen is much more rapid than that of adding iron oxide. The other was the addition of oxygen to the open-hearth flame, giving higher temperatures, quicker melt downs and refining operations.

Milwaukee

The first meeting of the season opened Friday, Sept. 28, 1951, at the Ambassador Hotel. All members and friends who had reservations were invited to the Social Period for Cocktails "on the house" which preceded the dinner. Sixty-eight attended with a large fill-in for the after-dinner movie and evening lecture.

Speaker for the evening was S. A. Greenberg, Technical Secretary of the American Welding Society. Mr. Greenberg presented his subject "Applied Welding Engineering," a 35-mm. film strip recently made available by the American Welding Society. Mr. Greenberg did the vocal accompaniment. The record which was to accompany the film cracked in shipment. Mr. Greenberg's subject aptly described the basic elements of fabrication and associated problems from conception to the finished items. The discussion after the lecture did him justice as it was only with difficulty that he was pried loose from the group so that the Chairman could close the meeting.

The regular meeting dates for the remainder of the season are as follows: Friday, Nov. 16, 1951; Friday, Dec. 14, 1951; Friday, Jan. 25, 1952; Friday, Feb. 22, 1952; Friday, Mar. 28, 1952; Friday, Apr. 25, 1952; May Party, May 24, 1952; 1952 Educational Course, January 14th, 21st, 28th and February 4th.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New Jersey

An interesting symposium on a timely subject, Inert-Gas Shielded-Metal-Arc Welding, was held as the first meeting of the season of the New Jersey Section, on September 18th. The fundamental concepts of the process as related to the welding of carbon, low-alloy and stainless steels was discussed by F. J. Pilia, Development Engineer, The Linde Air Products Co., Newark, N. J. It was pointed out that sigma-grade argon has increased welding speeds appreciably with ferrous alloys and has made welding possible with larger-diameter rod and lower currents.

Harold Robinson, Research Engineer, Air Reduction Co., Murray Hill, N. J., presented research data on nonferrous applications of the process, pointing out that helium and mixtures of helium and argon show some advantages for some applications.

The practical application of the sigma process for surfacing and welding with stainless steel was discussed by Arnold Rose, Director of Research and Development, Special Products Div., I.T.E., Circuit Breaker Co., Philadelphia, Pa. It was pointed out that the welding speed on a plug-welding operation on a jet-engine subassembly was increased eightfold by the process compared to tungsten-arc welding.

Frank Portik, Welding Supervisor, Alloy Fabricators, Perth Amboy, N. J., pointed out practical applications of the process for fabricating heavy-walled aluminum tanks and vessels. Sound welds at reduced costs was a salient feature of the process on these applications.

New York

The following is the program of meetings to be held at Schwartz's Restaurant, 54 Broad St., New York City, on the dates mentioned. All are on Tuesday. Sept. 11, 1951, "Fabrication of Welded Pressure Vessels," W. B. Bunn, Manufacturing Engineer, M. W. Kellogg Co.; Oct. 9, 1951, "Pipe Welding in Steam-Power Generation," C. A. Kelting, Assistant Division Engineer, Consolidated Edison Co.; Nov. 13, 1951, "Pipe Welding in the Petroleum Refining Industry," A. W. Zeuthen, Mechanical Engineer, Socony Vacuum Oil Co.; Dec. 11, 1951, "Brazed Piping Systems for Industrial and Building Installation," L. G. Pick, Sales Engineer, Walworth Co. Inc.; Jan. 8, 1952, "Pipe Welding Codes," F. S. G. Williams, Mgr. of Engr. Stds., Taylor Forge & Pipe Works; Feb. 19, 1952, "Metallurgy and Welding in Modern Turbine Design," N. L. Mochel, Chief Metallurgist, Westinghouse Electric Corp., Steam Turbine Div., So. Philadelphia; Mar. 11, 1952, "Recent Developments in Welded Bridges and Buildings," Frederick H. Dill, Welding Engineer, American Bridge Co., Ambridge, Pa.; Apr. 8, 1952, "Maintenance Repair and Casting Salvage," K. Spicer, Welding Engineer, International Nickel Co., and May, 1952, Annual Social Meeting. To be announced.

Niagara Frontier

On Thursday, September 27th, a dinner meeting was held in conjunction with the Whitehead Metals Welding Clinic at the Whitehead Metal Products Co. Warehouse, Buffalo, N. Y., with an attendance of 208 at dinner and 186 at the meeting following.

Fred L. Plummer, Director of Engineering, Hammond Iron Works, Warren, Pa., presented a very interesting address on "Fabricating and Erecting Field Structures." A half-hour discussion followed.

Dinner was donated by the Whitehead Metal Products Co. Inc., in their new warehouse opening by holding a three-day welding clinic with several forums and many operating exhibits. The Section was honored by the presence of J. G. Magrath, Secretary of the A.W.S., and Ove Green, Assistant Technical Secretary.

Northern New York

The first fall meeting of the Northern New York Section was held Thursday, October 4th at the Circle Inn, Lathams, N. Y. The speaker was R. L. McManus of General Electric Co., Aircraft Gas Turbine Div., who spoke on "Jet Propulsion in the Aircraft Industry." His talk was supplemented by two movie films, "Fundamentals on Jet Propulsion," a G. E. film, and "Jets Over Korea," an Army Air Force film.

This meeting was preceded by a dinner at which J. P. Frandsen was presented the Past-Chairman's pin.

The meeting was attended by about 50 persons.

Northwest

The first meeting of the Northwest Section of the season was held on Monday, September 10th at The Covered Wagon where Paper Calmenson & Co. was host to a group of 67 members of the Society.

As a part of the program enjoyed by the group a movie, "Wings Over Hawaii," was shown.

Pittsburgh

A plant visit was made to the Westinghouse Corp., East Pittsburgh Works, on Friday afternoon, September 21st. Sixty-nine were present at dinner at the Jacktown Hotel, Irwin, Pa., at 12 noon.

The conducted tour was made through the Metals Joining and Welding Research Laboratories, Welding Aisles and Welding School. The tour lasted three hours. Groups were made up of six to eight each, with experienced guides in charge, who explained and pointed out matters of interest as groups progressed from point to point. Demonstrations presented were particularly interesting, and the opportunity to witness actual assembling and welding of heavy structures was greatly appreciated.

Portland

A dinner meeting was held on September 18th. This was the first meeting of the year under the new officers.

Speaker at the meeting was A. B. Tesmen of the Tempil Corp. His subject was "Preheating for Welding." His talk was accompanied by slides, giving an informative and thorough discussion on the instances where preheating is either necessary or advocated before welding. The slides showed pictures of definite jobs where preheating had been required and showed the results obtained by using preheating. To enable the audience to get a good grounding in the factors inducing preheating, a thorough summary was made of the iron-carbide diagram theory.

Altogether, it was a highly instructive lecture.

Saginaw Valley

A Smorgasbord dinner was enjoyed by an attendance of 104 on September 13th at the Zehnders Hotel, Frankenmuth, Mich.

An excellent, extemporaneous talk was given by Roland Ogden, President of Aladdin Rod & Flux Mfg. Co., on Welding of Zinc-base Alloys (white metal) and brazing of aluminum.

A film "Realm of the Wild" was shown and enjoyed by all. Attendance at the meeting was 125.

Salt Lake City

The initial dinner meeting of the 1951–52 season was held on September 20th at The Hot-Shoppe Restaurant, Salt Lake City, Utah.

A 10-minute talk was made by Ed Fraser, Mgr., The Chicago Bridge & Iron Co., on the "Scope and Objectives of the A.W.S."

Al Drake of the Whitmore Oxygen Co. was the speaker at the technical meeting. His subject, "Hardfacing" as it applies to the welding industry, included the functions and economies with hardfacing, when and how it should be used and the advantages of using it.

Susquehanna Valley

The new officers for the 1951–52 season of the Susquehanna Valley are happy to announce that they have been able to obtain some very worth-while speakers who will discuss subjects of timely interest.

The first meeting was held Wednesday, October 3rd, in the dining room of the Berwick Golf Club, at which time a delicious dinner was served.

Kenneth M. Spicer of the International Nickel Co. was the guest speaker. The subject of his talk was "Maintenance Repair Procedures for Nickel and High-Nickel Alloys." Mr. Spicer covered the general properties of the base materials, basic welding procedures, sources of trouble, their effects and their elimination. Special emphasis was directed toward conservation of scarce materials through proper fabrication and maintenance procedure.

Western Michigan

The Western Michigan Section held a dinner meeting on Monday, September 24th, at the Elks Club Cafeteria, Grand Rapids, Mich., with an attendance of 60 at dinner and 69 at the meeting.

An Encyclopedia Brittanica film on the Fur Trapper of the North, in color, was shown during dinner, and proved very interesting to all.

C. A. Heffernon, Supervisor of Process Service of The Linde Air Products Co., Indianapolis, Ind., gave a good presentation of the subject, "Welding by the Sigma Process." A machine was set up in the cafeteria to give an actual demonstration of the sigma process. Samples were provided so that each member could actually operate the machine. Live demonstrations such as this prove interesting and draw a capacity crowd.

Worchester

A dinner meeting was held on September 26th at the Tower House, Worcester, Mass. John W. Mortimer of the Whitlock Manufacturing Co., Hartford, Conn., gave an excellent, extemporaneous talk on The Inert-Arc Process. A film "Stainless Steel" was shown through the courtesy of the Worcester Chamber of Commerce. A question-and-answer period followed the main part of the meeting.

abstracts of
CURRENT WELDING PATENTS

prepared by V. L. Oldham

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2,565,750—Jaws for Welder's Bench Tongs—Louis R. Bertino, Sidney, Mont.

This patent is on a special welder's bench tongs that are adapted to grip the workpiece in such a way that the welder may grasp and hold the tongs and work in one hand with the other hand free to perform other activities. The tongs include crossed linearly straight handles with one straight jaw portion being provided and the other jaw having progressively enlarged longitudinally spaced bends therein. Each handle and its companion jaw is of one-piece construction.

2,565,953—Low Alloy Steel of High Mechanical Strength, Little Sensitive to Quenching, Weldable, Etc.—Vittorio De Gaspari and Aldo Bartocci, Terni, Italy, assignors to "Terni" Societa per l'Industria e l'Elettricita, Terni, Italy, a company of Italy.

This patent covers a special weldable steel of high tensile strength. The steel contains in addition to iron from 0.14 to 0.26% carbon and small amounts of silicon, manganese, nickel and chromium. At least one element in the proportions specified from the group of up to 0.30% molybdenum, up to 0.25% vanadium and up to 0.80% copper is also present in the steel.

2,566,011—Method of Brazing and Removing Excess Brazing Material—Thomas Paul Williams, Dayton, Ohio, assignor to General Motors Corp., Detroit, Mich., a corporation of Delaware.

This bonding method relates to the use of dissimilar bonding material with metal bodies to bond them together at contiguous surfaces into a chambered construction. The bodies are adjusted with an excess of raw bonding material between them so that the bodies provide a low point in the chamber towards which all body surfaces slope downwardly and a porous collector body is disposed at such low point, which collector body has an affinity for the bonding material. The adjusted bodies are cycled through a bonding action by which the bonding material is melted and combined with the metal bodies and the excess bonding material drains to the lower point for collection. Thereafter the collector body is removed at the completion of the bonding cycle.

2,566,339—Brazing Paste—Louis G. Klinker, Griffith, Ind., assignor to The Glidden Co., Cleveland, Ohio, a corporation of Ohio.

Klinker's patent covers a special paste that essentially comprises a major amount of joining-metal paste dispersed in a minor amount of a synthetic polymeric heat-depolymerizable hydrocarbon gel vehicle having a Conradson carbon value below about 0.5%.

2,566,670—Flash Welder—Alfred H. Lewis, Huntington Woods, Mich., assignor to Swift Electric Welder Co., a Corporation of Michigan.

This flash welded has a base with a fixed platen and a movable platen positioned on the base. Each platen has an electrode and means for clamping work to be welded together to each electrode. A manually operable member is provided for initiating movement of the movable platen toward the fixed platen and other means associated with the movable platen initiate control means to increase the speed of the movement of the movable platen. A stop limits the movement of the movable platen towards the fixed platen and means are provided for cutting off the welding current prior to the completion of the advancing movement of the movable platen. Additional control means are provided to reverse the movement of the movable platen at any time during and after the completion of the advance or forward movement of the movable platen.

2,567,012—Combined Pressure-Welding Method—James Arthur Donelan, West Harrow, England, assignor to the General Electric Co., Ltd., London, England.

Donelan's welding method comprises the steps of scratch brushing the areas of contact of two aluminum pieces to be joined together and placing such surfaces in contact with each other. Pressure is applied to cause the metal of such surfaces to cold flow into intimate contact and the metal surrounding the cold weld is subjected to heat of a temperature to cause the metal to fuse and flow at the cold-weld surfaces.

2,567,020—Apparatus for Forming Continuous Welded Tubing—George B. Kueter, Dearborn, Mich.

This apparatus is adapted to form a tube from a strip of material in spirally wound condition. A supporting structure is provided and a cylindrical forming head is journaled for rotation on the supporting structure. Welding apparatus is carried by the forming head for welding the adjacent edges of a spirally wound strip together and for moving the strip longitudinally in response to rotation of the forming head.

2,568,074—Torch-Handling Apparatus—Ernie L. Launder, Montebello, Calif.

This torch-handling machine includes a base which has an elongate main carriage movably supported on the base; an upper elongate horizontal carriage that is pivotally mounted on the main carriage and movable therealong; a carrier mounted on the upper carriage for movement with relation thereto; and operative means for the carrier. Such means include a manually engaged control at one end of the upper carriage and a handle supported by the carrier.

2,568,222—Portable End-Welding Device—John C. Crecca and Elizabeth and Walter E. Palmer, Cresskill, N. J.

This patent relates to a specialized gun type of welding apparatus adapted for the arc welding of studs, bolts, etc., to the surface of a metallic plate. The apparatus includes two different plungers in the apparatus for aid in controlling the action thereof.

2,568,464—Electric Welding System—George L. Rogers, Schenectady, N. Y., assignor to General Electric Co., a corporation of New York.

Rogers' patented welding system includes the combination of a supply circuit, load circuit and a capacitance. Means are provided for charging the capacitance from the supply circuit and means responsive to the voltage of the capacitance are present to prevent operation of the charging means when the voltage of the capacitance attains a predetermined value. Other means are included in the combination for charging the capacitance to effect energization of the load circuit, and means responsive to the discharge current of said capacitance to control the charging means to recharge the capacitance are provided.

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Seam Welding of Monel Metal

Optimum condition for seam welding of Monel sheet in thicknesses ranging from 0.010 to 0.062 in. Satisfactory seam welds require no porosity in the nugget, good penetration, sufficient overlap and wide current range

by Ernest F. Nippes and Gerald M. Slaughter

Abstract

This research covers the seam welding of Monel sheet in five different thicknesses from 0.010 to 0.062 in. Optimum conditions were determined for each thickness of material and the factors determining the proper values of the welding variables are discussed. The criteria of satisfactory seam welds are: (1) no porosity in the weld nugget, (2) good nugget penetration, (3) sufficient weld overlap to insure a pressure-tight seam and (4) a wide current range. The welding current range varies with the thickness, the upper limit being determined by the point at which expulsion occurs for the thicker gages, and the point at which electrode sticking occurs with thicknesses below 0.062 in. The pillow test was found to be a valuable aid in determining the strength and pressure tightness of seam-welded joints. Methods of decreasing the tendency for sticking of the Monel sheet to the welding electrodes are discussed.

INTRODUCTION

IN 1939, a long-range program was undertaken at the Welding Laboratory of Rensselaer Polytechnic Institute to establish optimum resistance welding conditions for nickel and high-nickel alloys. It was felt that the determination of these optimum conditions and the investigation of the welding characteristics of these high-nickel alloys would be of considerable help to the fabrication industry. The research was sponsored by the International Nickel Co., Inc., and has been continuous up to the present date.

In previous phases of this long range program, the optimum spot,[1] flash[2] and cross-wire welding[3] conditions for several alloys were established. Before its completion, a thorough investigation of seam-welding problems was needed and the determination of optimum seam welding conditions for several alloys was to be made.

The principal aim of the section of the program described in this report was the determination of the optimum seam-welding conditions for five thicknesses of Monel sheet. These optimum conditions were considered to be those which gave sound, high-strength, pressure-tight welds over the widest range of welding current. A considerable investigation was performed on ways of minimizing sticking of the electrodes to the material being welded.

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This paper is based on a thesis that was presented in partial fulfillment of the requirements for a Master's Degree by Gerald M. Slaughter.

Table 1—Mechanical Properties of Annealed Monel Sheet

Thickness, in.	*Heat*	*Yield strength, psi.*	*Tensile strength, psi.*	*Elongation, %*
0.062	M4021B	33,200	74,100	43.0
0.031	M4021B	29,900	75,500	47.0
0.021	M4021B	32,400	78,400	40.5
0.015	M4021B	31,900	77,800	44.0
0.010	M4021B	32,300	75,200	42.0

MATERIAL

This investigation was performed on cold-rolled and annealed sheet in the 0.062-, 0.031-, 0.021-, 0.015- and 0.010-in. thicknesses. All welds were made on stripe 1 in. wide and 12 in. long with the exception of those made on pillow-test specimens. In this investigation, the pillow test specimens were constructed of sheets which were 6 x 6 in.

The mechanical properties of Monel sheet in the various thicknesses investigated are given above in Table 1.

The chemical analysis of Heat M4021B is given below in Table 2.

Table 2—Chemical Analysis of Heat M4021B

Element	%
C	0.09
Mn	0.96
Fe	1.52
S	0.005
Si	0.10
Cu	28.36
Ni	68.94

Material Surface Treatment

The as-received material possessed a bright surface finish with no visible surface oxide. It did, however, have a thin film of oil on its surface which might be detrimental in the production of consistent welds, and therefore all material was degreased prior to welding by immersion in boiling trisodium phosphate. Other suitable methods for degreasing the stock might include vapor-degreasing with trichloroethylene or polychloroethylene, or swabbing with carbon tetrachloride.

Surface contact resistance measurements were made with a Kelvin Double-Bridge circuit. The measurements on all thicknesses of Monel sheet after degreasing showed values ranging from 900 to over 1100 microhms. As wide variations in weld strength often result from high values of surface contact resistance, it was deemed advisable to pickle all the Monel to reduce this resistance to a low value.

A 50% nitric acid solution was used for flash pickling, which lowered the surface contact resistance to a low value, usually below 40 microhms. Typical values of this resistance for 0.062- and 0.010-in. Monel sheet are shown below in Table 3. Each of the measurements for each thickness were made on the same two strips of material. These values illustrate the consistencies which accompany low magnitudes of contact resistance.

Table 3—Typical Values of Surface Contact Resistance for 0.062- and 0.010-In. Monel

S.C.R. for 0.062-in. stock, microhms	*S.C.R. for 0.010-in. stock, microhms*
35	28
40	30
38	32

A pickling time of 10 sec. was found to be the most desirable from the standpoint of obtaining consistently low values of contact resistance. Shorter times did not allow sufficient pickling to occur, and times longer than 20 sec. apparently raised the contact resistance over the minimum value. With new solutions, the pickling action is somewhat slow, but it increases to a constant value after a short time. This fact, however, does not need to be taken into account for ordinary conditions.

EQUIPMENT

The seam welder used for the investigation was of the press type with a transformer rating of 175 kva. at 440 v. and 60 cycles. Power was supplied by a 350-kva. motor-generator set, the motor being driven from a 3-phase, 4160-v. line. Compressed air provided the pressure to the head of the welder, and the maximum available electrode force was 3100 lb. A heavy spring can be used to counteract the weight of the welder head when welding the thinner gages. Horizontal extensions were bolted to the electrodes when welding these thin gages in order to reduce inertia in the system, as will be explained later in greater detail.

The welding electrodes were driven by a variable speed Reeves drive. Bearings of the machine were internally water cooled, while the electrode surfaces and the material being welded were externally cooled by water.

The recommended welding electrodes were of an R.W.M.A. Class 2 electrode material and had a nominal diameter of 10 in. This particular electrode is recommended in the literature for seam welding Monel and was likewise found to be the best of those tested in the investigation. Typical physical and mechanical properties of this material are listed in Table 4.

Table 4—Typical Physical and Mechanical Properties of an R.W.M.A. Class 2 Alloy

Rockwell B Hardness	80
Electrical conductivity, % I.A.C.S.	80
Ultimate strength, psi.	75,000
Elongation, % in 2 in.	15
Annealing temperature, °F.	930

In an effort to alleviate the sticking of the electrode to the Monel sheet an R.W.M.A. Class 1 electrode was investigated. No improvement was found when using this electrode material.

The welding current was regulated by means of phase control of the ignitron tubes in series with the primary of the welder transformer. The timing control system was of the synchronous electronic type.

The presence of porosity and cracking in the seam welds was determined by radiography. A 150-kv. Industrial X-ray unit was used for this test. Eastman Type "M" X-ray film was used because of its extremely fine grain emulsion. Porosity could be detected easily by the use of this film, even when it was present in welds in the 0.010-in. sheet.

For the measurement of welding current an Esterline-Angus Recording Ammeter was used. When seam welding, a current trace was recorded which was pulsating, but which actually measured the rms. current over the total welding cycle, that is, the "on" plus the "off" time. A relationship was set up which permitted the calculation of the rms. current during the actual weld time. This relationship includes the ratio of "total" time to "weld" time and is expressed in the following formula:

$$I_{rms} = \sqrt{(I_{av.})^2 \times \left[\frac{\text{"Total" time}}{\text{"Weld" time}}\right]}$$

where

I_{rms} = the welding current.
$I_{av.}$ = the average of the pulsating recorded current.

This method of measuring current was checked with a pointer-stop ammeter and an I^2t meter[4] and an excellent correlation was found to exist.

This recording ammeter was connected in the primary circuit of the seam welder by means of a current transformer. The value of current obtained from the ammeter must, of course, be multiplied by the turns ratio of the current transformer and the turns ratio of the welding transformer before the actual welding current can be found.

The hydraulic system used to test the pillow specimens consisted of a hand-operated pump with a maximum capacity of 3000 psi. to supply the necessary pressure, and a hydraulic gage to measure the pressure. The fluid used was water to which about 5% of a soluble oil had been added.

PROCEDURE

It was found that the most satisfactory procedure for determining the optimum seam-welding conditions in Monel was that which is described in the following paragraphs.

For each thickness of Monel investigated, seam welds were made at various values of electrode force using a reasonable timing cycle and weld spacing. This timing cycle and weld spacing was chosen from experience and, of course, would vary with the sheet thickness. The minimum value of electrode force was determined which would eliminate porosity in the weld nugget. Then using this electrode force and the above weld spacing with a suitable "off" time, seam welds were made with varying values of "on" time. The best weld "on" time was that which was long enough to result in adequate fusion over a wide range of welding current and yet which would not cause sticking of the material to the electrodes. A more thorough investigation of "off" times was then made by using the previously determined electrode force and "on" times to produce welds with varying values of cool-time at a constant weld spacing. The optimum value of "off" time was that which was of sufficient length to eliminate porosity and prevent sheet discoloration, while being short enough to permit a relatively fast welding speed. It should be realized that in order to obtain the same weld spacing with varying welding timing cycles, the wheel speed must be changed.

Series of welds were then made by using the conditions determined above and varying the welding speed. The optimum value of weld spacing was that which allowed the attaining of an approximate weld overlap of 10–20%. The strength and pressure tightness of welds formed by using the determined optimum conditions

were then checked by the use of the pillow test. A more detailed discussion of the determination of the optimum value for each variable is given in the ensuing paragraphs.

Thus by a judicious choice of values for the welding variables, the amount of work required to determine the optimum conditions for a given thickness is considerably reduced.

Determination of Electrode Force

The principal factor governing the selection of the proper electrode force for a given thickness of material is porosity. There is a minimum value of this variable below which satisfactory welds cannot be made. The welds made with electrode forces below this minimum may have varying degrees of porosity or voids, but, in any case, they are considered to be defective. A photomicrograph and a photomacrograph of a seam weld containing porosity are shown in Figs. 1 and 2. Radiography was used to determine the presence of this condition, and prints of radiographs of sound and defective welds are shown in Figs. 3 and 4.

A weld defect, similar to porosity, that is sometimes encountered is cracking in the weld nugget. A photomacrograph of a weld exhibiting cracking is shown in Fig. 5. Cracks are easily propagated and may lead to failure of the welded joint. When it occurs, cracking is generally found along with porosity. Radiography is useful in detecting this condition since the fissures appear as dark stringers in the

Fig. 1 Seam weld containing porosity. 100 ×

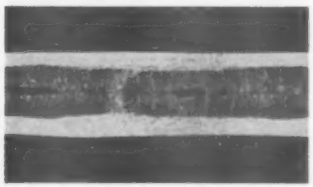


Fig. 2 Seam weld containing porosity. 18 ×

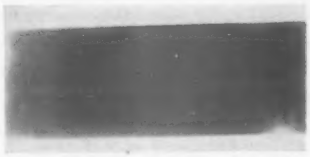


Fig. 3 Print from a radiograph showing a sound weld

Fig. 4 Print from a radiograph showing porosity

negatives, but metallographic sectioning will also disclose its presence. Cracking was found in Monel seam welds primarily when using very long weld times with low values of electrode force. However, in welding this alloy, conditions which eliminated porosity also eliminated cracking.

Cracking in the weld nugget should not be confused with the phenomenon known as "coring."[1] Coring may be seen in Figs. 6, 9 and 10 as small stringers at the corners of weld nuggets. These at low magnifications appear to be cracks, but at higher magnifications it may be seen that these areas are composed of dendritic material. These dendritic areas are caused by melting along the grain boundaries at critical points near the weld nugget.

Excessive electrode force often results in distortion and indentation in the sheets. Also, in seam welding Monel it was found that the loss of surface contact resistance, and therefore fusion, was rapid with increasing force. Since this loss in contact resistance calls for an increase in welding current to insure sufficient fusion, considerably higher currents must be used for the larger values of electrode force. These high currents greatly aggravate the condition of electrode sticking, and it was found that this condition became so bad with electrode forces high enough to cause excessive distortion that extreme difficulty was encountered in making welds.

The optimum values of electrode force listed in Table 5 are, in all cases, those which are just sufficient to eliminate porosity.

Determination of Weld Time

It is a characteristic of resistance welding that narrow welding current ranges accompany short weld times. When welding Monel, long weld times increase sheet distortion, cracking, and the tendency to-

Fig. 5 Cracking in a seam weld. 25 ×

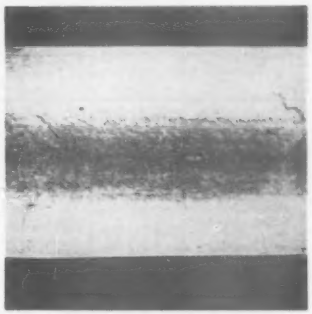


Fig. 6 Longitudinal section of a seam weld showing only slight fusion. 25 ×

wards the sticking of the sheet to the electrodes. Thus, these factors tend to set the lower and upper limits of "on" time that may be used.

High currents quite often are necessary when using short weld times and this might be a deciding factor when welding the thicker gages if the power supply is limited. Since the welding current range is limited, expulsion of metal may occur very close to the fusion range when welding with short times. In addition, short times inhibit the softening of the metal around the electrodes during welding, thus preventing adequate follow-up with the consequent formation of voids or porosity. Consequently it may be seen that relatively short weld times may not be too desirable in seam welding Monel.

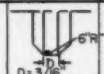
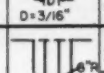
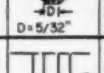
As indicated above, the upper limit of the "on" time may be restricted by the problem of electrode sticking. However, this problem is more important when welding the thinner gages of Monel because the ratio of surface contact resistance to the total resistance is greater. In the 0.010- and 0.015-in. Monel, for example, the problem becomes acute. In fact, the thinner gages could not be welded without electrode sticking unless special precautions were made. Methods used for minimizing sticking are discussed in another section.

The weld time must therefore be short when working on the thin material. One-cycle welds were found to be optimum for the thinnest gages, while half-cycle welds were found to be entirely satisfactory.

Determination of Weld "Off"-Time

The variable which is known as the

Table 5—Recommended seam welding conditions for Monel

Set-up Variables			Welding Variables					Fusion Analysis			
Thickness and gage	Electrode Shape	Electrode-Force (lbs)	Timing Cycle "On" time	Timing Cycle "Off" time	Weld Spacing Welds/inch	Wheel Speed in/min	Welding Current (amps)	Width of Fused Zone (in)	Weld overlap	Weld Penetration	
0.062" 16		2500	8	12	9	20	19,000	0.17	10%	35%	optimum
		2400-2600	6-10	8-15	7-11	--	16,000-21,000	0.0-0.25	0-15%	0-40%	Permissible range
0.031" 22		700	4	12	12	19	10,000	0.15	20%	40%	optimum
		600-800	3-6	8-15	10-14	--	8,500-11,000	0.0-0.18	0-25%	0-45%	Permissible range
Electrodes Unburnished		600	3	12	11	22	9,500	0.15	10%	35%	optimum
0.021" 25		500-700	2-4	8-15	10-12	--	8,000-10,000	0.0-0.18	0-15%	0-40%	Permissible range
Electrode Burnished		500	2	6	12	38	8,700	0.15	20%	40%	optimum
0.021" 25		400-600	1-3	4-8	10-14	--	7,200-8,900	0.0-0.18	0-25%	0-50%	Permissible range
Electrodes Burnished		300	1	3	12	75	7,600	0.10	15%	35%	optimum
0.015" 29		250-350	1/2-1 1/2	2-4	11-13	--	6,800-7,800	0.0-0.11	0-20%	0-40%	Permissible range
Electrodes Burnished		200	1	3	12	75	5,300	0.09	15%	30%	optimum
0.010" 32		150-250	1/2-1 1/2	2-4	11-13	--	4,800-5,500	0.0-0.10	0-20%	0-35%	Permissible range

"off"-time is a complex one. It can be used to great advantage in eliminating porosity. A short cool-time does not let much forging occur because the electrodes roll off the work while it is still in the hot-short range. By increasing the "off" time and consequently decreasing the wheel speed, to keep the weld spacing constant, significant changes in the amount of porosity or cracking can be attained. Of course, a balance must be chosen so that the welding speed will not be so low as to be impractical from a production standpoint.

Short "off" times also prevent sufficient cooling of the sheet surfaces with resultant discoloration and sticking. Monel is particularly prone to sheet discoloration and takes on a greenish tinge when overheated. Even with four jets of water impinging on a weld seam, this condition may not be alleviated.

It was found that values of "off" time greater than the "on" time are highly desirable when seam welding Monel. From experiments made on the 0.062-in. gage, cool-times of 12 cycles were found to be sufficient, and 3-cycle cool-times were determined to be the best for the 0.010-in. thickness.

Determination of Weld Spacing and Welding Current

The optimum spacing determination was performed along with the welding current measurements. The permissible current range varies somewhat with the number of welds per inch, and thus the suggested welding current may vary slightly with weld spacing.

As seam welding is characterized by a series of overlapping spot welds, an important variable is weld spacing. To insure pressure tightness, the number of spots per inch of seam weld must be sufficient to prevent leakage between weld nuggets. Through the use of the pillow test, it was found, as might be expected from experience with other metals, that welds do not necessarily have to overlap to obtain pressure tightness. However, some overlap is desirable to insure the seam weld against pressure failure if minor fluctuations occur in the welding variables.

A peculiarity noticed when seam welding Monel is that the weld spacing is very influential in the amount of fusion that is obtained. The short-circuit current (the current that is shunted through the preceding weld) is so great with a large number of welds per inch that there is little fusion. By the time the current is of sufficient magnitude to cause fusion, surface sticking and discoloration occur.

It will be noted that the optimum weld spacings for the 0.031-, 0.021-, 0.015-, and 0.010-in. gages are all 11 or 12 welds per inch. A faster welding speed will make the spots so far apart that pressure tightness may be impaired. When the speed is reduced to the range of 15 or more welds per inch, little or no fusion can be obtained before pronounced sticking occurs. Thus, the number of spots that will create a pressure-tight seam is rather critical, being limited on one hand by the lack of welds per unit of length, and on the other hand by lack of fusion due to the excessive short-circuiting effect.

A metallographic section of the condition of insufficient fusion is shown in Fig. 6. The etchant here, as in all of the metallographic work, was Modified Marble's Reagent. It may be seen that the usual columnar dendritic structure of a resistance weld is missing. A higher magnification picture of the zone of incipient fu-

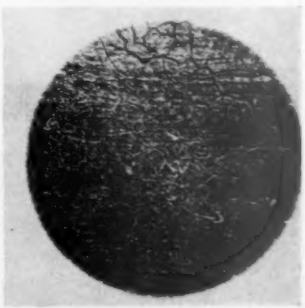


Fig. 7 Longitudinal section of a seam weld showing only slight fusion. 100 ×

sion between welds that do not overlap is shown in Fig. 7.

The optimum seam-welding conditions for each thickness of Monel sheet investigated are shown in Table 5. Photomacrographs of welds at optimum conditions and at current values just sufficient to produce a pressure-tight seam for each thickness are shown in Figs. 8 through 17.

The optimum conditions listed in Table 5 are those which gave the most satisfactory seam welds from the standpoint of soundness, penetration, nugget overlap, and maximum permissible current range. The suggested weld time was that which produced adequate fusion with a minimum of electrode sticking, porosity and sheet distortion. The weld "off" time was chosen from the standpoint of the minimization of sheet discoloration and weld porosity while allowing a fairly rapid welding speed. The recommended electrode force is that which will just eliminate porosity, while the optimum weld spacing is that which will produce approximately 10–20% overlap of the weld nuggets. The prescribed welding current was chosen as one which was not great enough to cause electrode sticking or expulsion, but yet which was sufficient to insure good fusion.

The permissible range of values for the welding variables lists the upper and lower limits with which passable welds can be produced. By using values in this range, which are not optimum values, welds can be produced which will be satisfactory under most conditions. However, it should be emphasized that these welds are lacking in some respect, and definite efforts should be exerted to use the recommended conditions.

After the optimum conditions were determined, the pillow test was used to evaluate the strength and pressure tightness of seam welds made under the recommended conditions. This test was used since it is the only test which approaches operating conditions of a seam-welded joint. The tensile-shear test is of no value in determining pressure tightness since high-strength welds may not have sufficient overlap to insure this. The normal-tension test is of little use because of the difficulty in obtaining equal cross-sectional weld areas in duplicate specimens.

The pillow test specimen, shown in Fig. 18, was constructed from two flat 6- x 6-in. sheets of Monel. Previous to seam welding, a small hole was drilled in the center of one sheet and a brass pipe nipple was centered over the hole and silver brazed to the sheet. The sheets were then placed together and tacked by spot welding in the corners to help in handling. Seam welds were then made parallel to the four edges so as to enclose a 4- x 4-in. area. The pillows were then sheared to within approximately $\frac{1}{8}$ in. of the outer edge of the seam before testing. The pillow specimens were attached to the previously described hydraulic system and the hydrostatic pressure gradually increased until rupture occurred.

Pillow tests were made on welds produced over a current range varying from that causing insufficient fusion to that resulting in expulsion or sheet sticking. The welds were remarkably pressure tight, and it was striking to note that high rupture strengths were obtained where

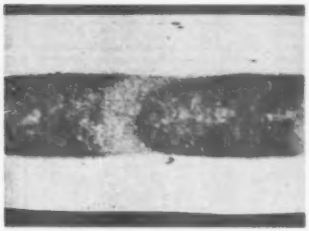


Fig. 8 Longitudinal section of a seam weld made in 0.062-in. Monel at optimum conditions. 18 ×

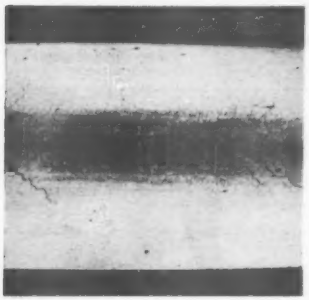


Fig. 9 Longitudinal section of a seam weld made in 0.062-in. Monel at a low current value. 18 ×

Fig. 10 Longitudinal section of a seam weld made in 0.031-in. Monel at optimum conditions. 18 ×

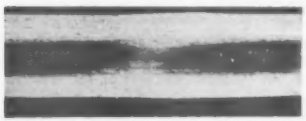


Fig. 11 Longitudinal section of a seam weld made in 0.031-in. Monel at a low current value. 18 ×

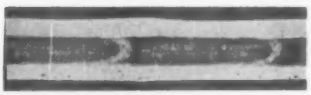


Fig. 12 Longitudinal section of a seam weld made in 0.021-in. Monel at optimum conditions. 18 ×

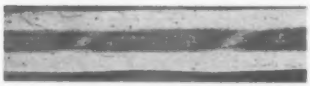


Fig. 13 Longitudinal section of a seam weld made in 0.021-in. Monel at a low current value. 18 ×

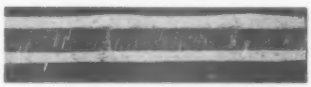


Fig. 14 Longitudinal section of a seam weld made in 0.015-in. Monel at optimum conditions. 18 ×

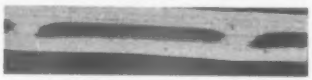


Fig. 15 Longitudinal section of a seam weld made in 0.015-in. Monel at a low current value. 18 ×

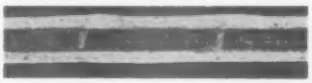


Fig. 16 Longitudinal section of a seam weld made in 0.010-in. Monel at optimum conditions. 25 ×

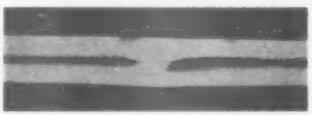


Fig. 17 Longitudinal section of a seam weld made in 0.010-in. Monel at a low current value. 25 ×

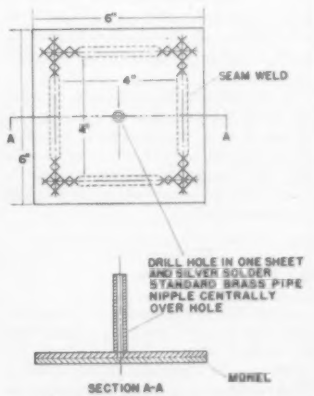


Fig. 18 Details of pillow test specimen

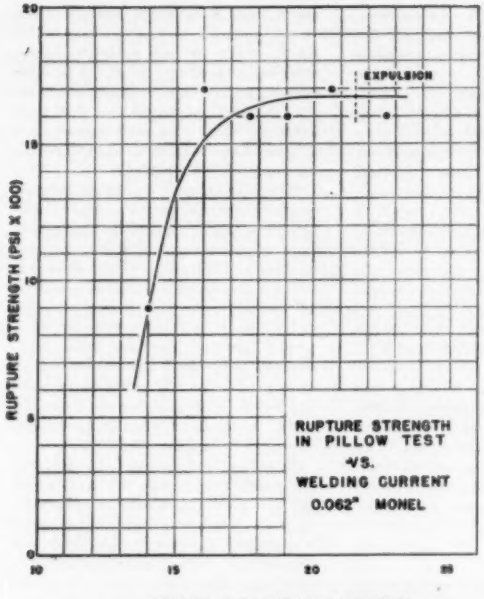
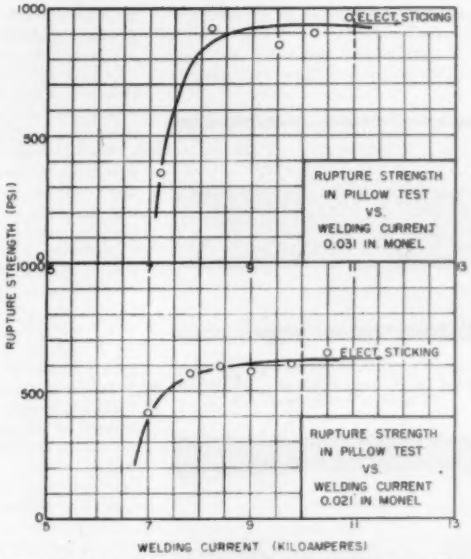

EXPULSION
RUPTURE STRENGTH IN PILLOW TEST VS. WELDING CURRENT 0.062" MONEL
RUPTURE STRENGTH (PSI X 100)
WELDING CURRENT (KILOAMPERES)

Fig. 19 Rupture strength in pillow test vs. welding current for 0.062-in. Monel sheet


ELECT. STICKING
RUPTURE STRENGTH IN PILLOW TEST VS. WELDING CURRENT 0.031 IN. MONEL
ELECT. STICKING
RUPTURE STRENGTH IN PILLOW TEST VS. WELDING CURRENT 0.021 IN. MONEL
RUPTURE STRENGTH (PSI)
WELDING CURRENT (KILOAMPERES)

Figs. 20 and 21 Rupture strength in pillow test vs. welding current for 0.031- and 0.021-in. Monel sheet

only a small amount of fusion was present. The rupture strength vs. welding current curves for each of the five thicknesses investigated are shown in Figs. 19 through 23. The higher values of rupture strength were those recorded for specimens which failed in the sheet adjacent to the weld seam and not for those that failed by shearing through the weld nugget itself. Failure of the specimen adjacent to the weld seam may have resulted from a form of stress concentration since considerable sheet deformation was observed during application of pressure. As an indication of sheet deformation, the total amount of bulge in a pillow-test specimen might be as great as 2 in. A typical pillow-test sample exhibiting this amount of bulge is shown in Fig. 24.

A plot of maximum rupture strength vs. sheet thickness is shown in Fig. 25. It will be noted that a straight line function is obtained, which seems to indicate that the maximum rupture strength is dependent to a large extent on the strength of the sheet itself.

DISCUSSION

Sticking

It has been emphasized that much of the difficulty involved in seam welding Monel is centered around the sticking of the sheets to the electrodes during welding. This problem of sticking is probably derived from the fact that the copper in the electrodes and the nickel-copper alloy of the Monel are so similar in structure that a diffusion bond occurs at the temperatures involved in the welding operation. The condition can become so serious that the sheets follow the electrodes during welding and have to be broken loose from them. In any case, the sheets become bent and misshaped weld nuggets are formed.

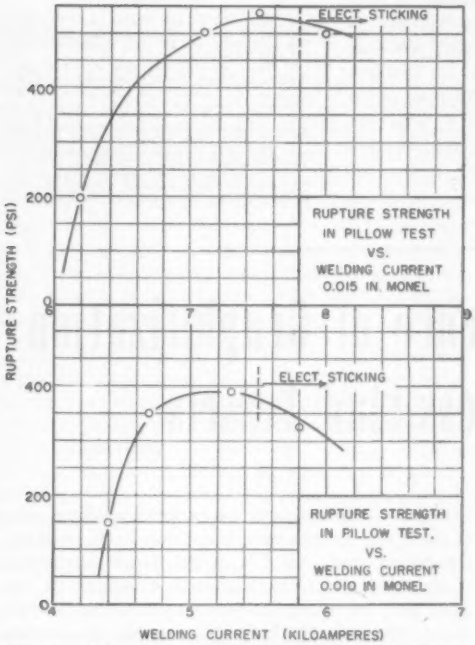
Numerous methods of reducing sticking were investigated, but only one was of sufficient value to permit the welding of the thinner gages. This method involved surface hardening the electrode wheels by cold working, which apparently obstructs the bonding and thus minimizes the sticking. The surface hardening of the electrode was done with a burnishing tool which fits in the tool holder of a metal lathe and has a hardened steel rod set in roller bearings so that it can rotate easily. The seam-welding electrode is rotated in the lathe and the burnishing tool is forced against the face of the rotating electrode causing cold working to occur. By careful manipulation of the tool, a smooth surface can be formed on the welding wheel. If a domed electrode is desired, the proper concavity can be machined on the hardened steel rod. A drawing of the burnishing tool is shown in Fig. 26.

One of the other methods for reducing sticking that was investigated consisted of using a narrower electrode face. This was tried with the hope that the sticking problem would be alleviated. It will be noted from the table of recommended conditions, Table 5, that the electrode width decreases with decreasing thickness of material as would be expected, but decreasing this dimension further has little beneficial effect.

Higher values of electrode force should theoretically decrease the contact resistance between the electrodes and the Monel strips and therefore lessen the heat developed at the surface. This is probably true, but the sheet-to-sheet resistance also decreases making it more difficult to obtain a weld. Thus, little reduction in sticking was gained from the use of higher pressures.

An electrode of R.W.M.A. Class 1 composition was also used in this respect. This type of electrode has a higher electrical conductivity than R.W.M.A. Class 2 and therefore less heat would be generated at the material surfaces during welding. The results were not too conclusive, but there was definitely no sharp decrease in the affinity for sticking. In any case, this class of electrode is softer than the Class 2 electrode recommended and the annealing temperature is considerably lower.

A few experiments were performed on Monel strips having a thin coating of yellow Vaseline on the surfaces. The results on this material were very erratic and were not at all reproducible. Apparently sticking was reduced somewhat by the coating but because of the inconsistencies, this method was abandoned.


ELECT. STICKING
RUPTURE STRENGTH IN PILLOW TEST VS. WELDING CURRENT 0.015 IN. MONEL
ELECT. STICKING
RUPTURE STRENGTH IN PILLOW TEST. VS. WELDING CURRENT 0.010 IN MONEL
RUPTURE STRENGTH (PSI)
WELDING CURRENT (KILOAMPERES)

Figs. 22 and 23 Rupture strength in pillow test vs. welding current for 0.015- and 0.010-in. Monel sheet

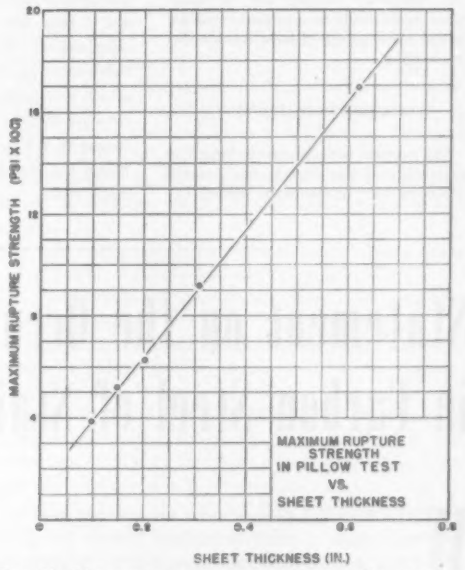


Fig. 25 Maximum rupture strength in pillow test vs. Monel sheet thickness

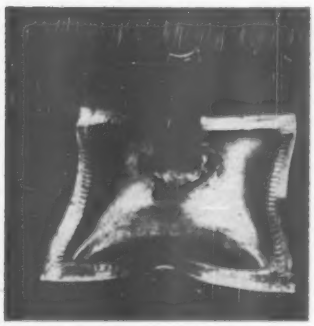


Fig. 24 Photograph of a tested pillow specimen

Inertia and Friction

The production of consistently good seam welds depends to a large part on adequate follow-up of the welding head to insure adequate forging and a uniform application of pressure as the wheel rolls along the weld. In a high-inertia machine, the failure to attain sufficient follow-up may be of great importance. Porosity may thus result from the failure to reduce inertia in the head of the welding machine. It should be realized that the inertia factor becomes considerably more important as the thickness of the material being welded decreases.

Extensions were added to the top and bottom electrodes when welding the thin material. Ordinarily the welding wheels are almost directly under the source of pressure. In this position, the electrode follow-up is based primarily upon the inertia of the welder head. The extensions, which are approximately 6 in. in length, were bolted to the copper electrode arms. The welding wheels were fastened to the other end of the extensions. This simulates a cantilever system where the wheels are no longer under the source of pressure. The extensions deflect elastically and therefore help to improve the follow-up. By alleviating the high-inertia condition, porosity in the weld nugget can be minimized.

Friction, which is also an important factor in the formation of porosity in the welds can be reduced by frequent lubrication of the welding machine. The usual type of flexible conductor in the upper electrode arm is of the laminated copper type. The friction between the laminations hindered electrode follow-up when seam welding. This frictional effect was greatly reduced by replacing the laminated conductor with several woven copper cables. As a result, much more consistent results were obtained when seam welding the thinner gages.

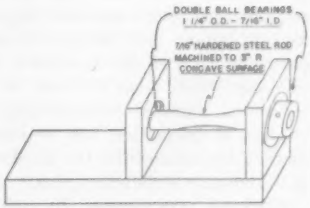


Fig. 26 Diagram of burnishing tool

CONCLUSIONS

1. The optimum seam welding conditions for 0.010-, 0.015-, 0.021-, 0.031- and 0.062-in. Monel sheet have been determined. These conditions were recommended because they resulted in the production of sound, high-strength, pressure-tight welds over a wide range of current.

2. To insure the best welding consistency, it is important to carefully clean and pickle the Monel prior to welding.

3. Radiography is an excellent means of detecting the presence of porosity and cracking in seam welds.

4. Metallographic sectioning should be used extensively when performing seam-welding research for it is the only positive way of determining the amount of fusion and weld overlap.

5. The pillow test is a valuable aid in determining the strength and pressure tightness of seam welds.

6. Electrode sticking can be minimized considerably by a process involving surface cold-working of the electrodes before welding.

ACKNOWLEDGMENTS

The authors wish to acknowledge the sponsorship of this experimental investigation by the International Nickel Co. The authors also wish to thank Dr. Wendell F. Hess, Head of the Department of Metallurgical Engineering, Rensselaer Polytechnic Institute, for his invaluable advice and guidance. They are further indebted to Dr. William A. Mudge and Robert M. Wilson, Jr., of the International Nickel Co., for their help, guidance and cooperation.

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Statement on the Occurrence of Graphitization in Carbon Steel of Stainless-Clad Vessels

WHEREAS it had long been known that the carbide phase of plain-carbon and certain low-alloy steels is metastable, and breaks down to graphite when equilibrium is established, as by prolonged holding at elevated temperatures, it was not until the occurrence in 1943 of the now-famous failure, attributable to graphitization, of a steam pipe made of 0.5% molybdenum steel that this structural change was recognized to be of commercial importance in the service of carbon and certain low-alloy steels. This particular type of microstructural change is only one of many which occur in most all metals applied in service at elevated temperatures, and which cause changes in properties, but because of the localized distribution assumed by the graphite, failure occurred in the instance of the steam pipe.

Extensive examination by the power-generation industry revealed other instances of graphitization, which, however, with a few exceptions, had not progressed so extensively as in the failure in which it was first encountered. Numerous investigations of the variables affecting graphitization of steels have shown the importance of such factors as deoxidation practice, chemical composition and pre- and postheat treatment. The most effective and practical means of inhibiting graphitization in steam piping has proved to be the addition of the element chromium, and this has been accepted by the power industry for service in most new or replacement generating plants.

Unlike the power industry, which shifted to alloy steels with increase in operating temperature, the petroleum industry has found it expedient to continue using carbon steel at temperatures up to 1000 F. and higher, and furthermore, have in general, believed their installations to be free of or unaffected by graphitization. Early this year, however, austenitic-stainless-clad reactor vessels in the catalytic cracking units of three oil refineries were found to contain cracks in the carbon steel (A.S.T.M. A-201, Grade A) portion of the composite plates immediately adjacent to the main seam welds after about 60,000 hr. service between about 900 and 1000° F. Microscopic examination of samples from the cracked regions revealed an extensive system of intergranular cracks oriented normal to the plate surface, and characteristic of so-called "stress-rupture" failures. The cracks in the samples examined appeared to be located either in the weld heat-affected metal or just outside the heat-affected zone although all probably initiated near the edge of the weld overlay on the plate surface. In addition to the widespread intergranular cracking, it was also observed that graphitization, as well as carbide spheroidization had occurred. The graphite was in most cases of the scattered nodular type and was present in both the base metal and the weld heat-affected regions, but it has been reported that some few specimens showed very heavy concentrations of nodular graphite in heat-affected zones in a form which could be termed "continuous nodular" or "bead type." In only one specimen was there detected a form of graphite which bears a resemblance to the so-called chain type of graphitization, experienced in the Mo-steel steam-pipe fracture, and there is some question as to the correctness of the identification of graphite in this micro specimen.

Since the discovery of the first cracked reactors, samples have been taken in a number of other refineries both from reactors and from associated piping. Except for the three austenitic-stainless-clad reactors found to be cracked, none of the other reactors which have been examined have been found to be cracked.

Samples removed from other reactors, both clad, lined, and unlined, have been found to contain graphite in some cases and not in others. Although the association of cracking with welds in reactors clad with aus-

Prepared by a Subcommittee of the Materials Div. of the Pressure Vessel Research Committee, Welding Research Council, consisting of G. V. Smith, Chairman, H. F. Brown, F. Eberle and W. B. Hoyt.

tenitic stainless steels, and the general configuration of the cracking suggests that the primary cause of failure may have been the stress state generated at such sites owing to the restraints and stress concentrations at the welded joints and aggravated by the different thermal expansivities of ferritic and austenitic steels, it is possible that graphitization may have been an accessory. It appears too early to yet form a positive opinion in this matter. In any event, the broad question of the strength of welded joints in elevated temperature service, especially when affected by graphitization, is one about which comparatively little is known and should be a fruitful field of research.

The occurrence of cracking and the possible effects of graphitization on service life of petroleum refineries has aroused sufficient concern that the Committee on Refinery Equipment of the Division of Refining of the American Petroleum Institute, meeting in Tulsa in May, decided to submit a questionnaire to the industry to obtain information regarding service experience. They will also undertake a program of sampling equipment in service and will examine these in respect to microstructure, bendability, McQuaid-Ehn grain size and structure, and deoxidation practice. It is to be presumed that on the completion of such a survey, sufficient information should be available to permit assessing of the prevalence of cracking and of the influence on it, if any, of graphitization. Should the associated graphitization prove to contribute to the cracking, it will become necessary to select standards of rating severity of deterioration, i.e., need for replacement, and if the latter is required, procedures for so doing.

Should it be concluded that graphitization is only incidental or even entirely unrelated to the cracking, there still remains for consideration the rather broad question of the influence of graphitization on serviceability, and whether the permissible service pressures and temperatures should be prescribed according to the graphitization susceptibility of the steel. It should be exphasized in this connection that graphitization is but one of a number of microstructural changes which may occur in metals in service at elevated temperatures, and the effects of which have been only inadequately explored.

The question of graphitization in oil-refinery equipment is also being given active consideration by a Task Group of the Petroleum and Chemical Panel of the Joint A.S.T.M.-A.S.M.E. Committee on the Effect of Temperature on the Properties of Metals, who have elected to consider the following three aspects of the subject.

1. Effect of graphite on room and high temperature strength of carbon and carbon-moly steel
2. Weldability of graphitized carbon and carbon-moly steels
3. What controls should be and can be placed on carbon steel to produce optimum resistance to graphitization

Project 29 of the Joint A.S.M.E.-A.S.T.M. Research Committee on the Effect of Temperature on the Properties of Metals has been engaged for some time past in fundamental investigations, the purpose of which is to learn the factors that influence the susceptibility of steels to graphitization. At present they are sponsoring work at Battelle which involves the melting of pure alloys to study the effects of aluminum and nitrogen, aluminum in solution, manganese and silicon, and chromium.

As a result of the graphitization problem of the steam-power industry, many experimental investigations have been undertaken to elucidate the rules of various factors affecting graphitization. These studies have been made both by individual companies and by research groups under cooperative sponsorship, and a number are still continuing. Much light has been shed upon the subject, in so far as laboratory tests can do so, by these studies. However, the current and proposed investigations of graphitization are not designed to explain why cracking has occurred in austenitic-stainless-clad steel fabricated with composite welds nor will they explain why cracking in pressure vessels so frequently is located in the heat-affected zones of welded seams. Little work has been done on the elevated-temperature mechanical properties of welded joints despite the great importance of welded seams in pressure vessels.

Buckling of Intermittently Supported Rectangular Plates

Studies of the buckling behavior of long rectangular plates intermittently supported on one or both long edges with various supports and loadings

by C. H. Norris, D. A. Polychrone and L. J. Capozzoli

Synopsis

This paper deals with a research project being conducted in the Structural Analysis Laboratory of the Massachusetts Institute of Technology under the sponsorship of the Structural Steel Committee of the Welding Research Council. The ultimate objective of this program is to develop reliable specifications governing the use of intermittent fillet welds to connect the component parts of structural members.

When it is unnecessary to use continuous welds in order to satisfy the strength requirements of a connection, intermittent welds may be used. However, the clear space between such welds must be short enough to preserve essentially all of the local buckling resistance which the component parts of the member would possess if the welds were continuous. In many cases, the determination of the local buckling characteristics of welded struts and flexural members reduces essentially to a study of the buckling of long rectangular plates compressed on the ends and supported on the long edges in various manners.

This project has therefore been divided into four phases, the first two of which are being reported on in this paper. Phase I is a theoretical and experimental study of the buckling behavior of long rectangular plates intermittently supported on one or both long edges by a simple support and uniformly compressed on the ends. Phases II and III are similar to Phase I but designed to study the effects of clamping the long edges and of applying a triangularly distributed end compression, respectively. Phase IV, now in progress, involves testing typical structural members, and comparing their actual performance with the local buckling behavior predicted from Phases I, II and III.

Until Phase IV is completed, no recommendations can be made regarding specifications. Theoretical and experimental evidence to date demonstrate, however, that there is for an intermittently supported plate a rather large "critical gap-width ratio" below which the plate retains essentially all the buckling resistance of a continuously supported one.

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This paper was presented before the Thirty-First Annual Meeting, American Welding Society, Chicago, Ill., week of Oct. 22, 1950.

INTRODUCTION

IN RECENT years, there has been a growing interest in the evaluation of ultimate strengths of various types of structures. If the full capacity of a structural material is to be utilized so as to achieve the maximum possible ultimate strength in a structure, it is of course necessary that there be no premature buckling of the structure as a whole, or of any of its members. Local buckling of the component parts of these members may also decrease the ultimate strength of a structure. For example, local buckling of a cover or web plate of a compression member, or of a flange plate of a flexural member may cause premature buckling of the member as a whole. On the other hand, local buckling of the web plate of a beam would not seriously affect its ultimate load-carrying capacity if the vertical stiffeners were properly designed.

The designer should always realize, therefore, that local buckling of a component part may lower the efficiency of a member as a whole, and invite premature failure of an otherwise adequate structural member. In such cases, he should always strive to provide as much local buckling strength in the component parts as integral buckling strength in the member as a whole.

The integral buckling resistance of a compression or flexural member depends upon its bending and torsional stiffness. The local buckling resistance of a component part of such a member depends, however, upon the width-thickness ratio of the part and the manner in which its edges are supported.

The designer provides strength to resist local buckling by conforming with requirements such as the following which have been extracted from typical specifications for carbon steel members:

1. In compression members, the unsupported width, b, of a web plate must not exceed 32 times its thickness, t;

2. The clear space or gap, g, between intermittent fillet welds must not exceed 16 times the thickness, t, of the thinner plate joined.

Many feel that specifications such as these dealing with the local buckling of structural members involve problems which require further study and research. The project reported on in part in this paper was therefore set up with the objective of developing reliable specifications, similar to 2 above, governing the use of intermittent fillet welds to connect the component parts of structural members.

FORMULATION OF THE PROBLEM

Consider several typical welded compression members having cross sections such as shown in Figs. 1 (*a*) and 1 (*b*). If such compression members are axially loaded without eccentricity, elements *A* act as long rectangular plates loaded in their plane by uniform compressive forces on the two ends and supported in some manner along the two long edges. Elements *B* are also essentially long rectangular plates but in this case supported on only one long edge and free on the other.

Of course, if compression members are eccentrically loaded, the plate elements may be subjected to not only nonuniform end forces, but also shearing forces along the long edges—though the latter forces are usually small. If element *B* in Fig. 1 (*a*) represented the compression flange of a flexural member, it would then be subjected not only to possible end compression but also to shearing forces through the weld connecting it to the web. The width of the flange is a very small fraction of the length of a flexural member, and it is also often true that the shearing forces are small in the region of maximum flange compression. It is therefore usually possible to isolate a relatively long portion of such a flange plate, and then, neglecting the small shearing forces along the connection to the web, to consider this portion subjected only to end compressions.

Buckling failure of flexural and compression members may take place by local buckling of one of the plate elements, such as *A* or *B*, rather than by integral buckling of the member as a whole. To study completely all possible local buckling phenomena in such members would involve consideration of a large number of cases.

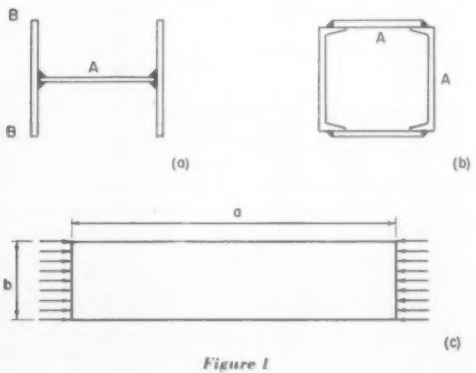

Figure 1

However, considerable may be learned concerning many of the most important buckling situations by studying the buckling behavior of long rectangular plates compressed on the ends and supported on the long edges in various manners. The ends of these plates may be considered to be simply supported—i.e., displacement normal to the plane of the plate is prevented, but the edge is free to rotate and move parallel to the plane of the plate. The types of support along the long edges should be varied widely from completely free to clamped (or fixed) against rotation.

This study of the local buckling behavior of structural members, the component parts of which are connected by intermittent fillet welds, has been divided into four phases: the first two of which have been completed and are reported on herein; the third is partially complete and temporarily delayed pending the delivery of the remainder of the test plates; and the fourth also is in progress. Phase I is a theoretical and experimental study of the buckling behavior of long rectangular plates intermittently supported on one or both long edges by a simple support and uniformly compressed on the ends. Phases II and III are similar to Phase I but designed to study the effects of clamping the long edges and of a triangularly distributed end compression, respectively. Phase IV involves testing typical structural members, and comparing their actual performance with the local buckling behavior predicted from Phases I, II and III.

When it is unnecessary to use continuous welds in order to satisfy the strength requirements of a connection, intermittent welds may be used. However, the clear space between such welds must be short enough to preserve essentially all of the local buckling resistance which the component parts of the member would possess if the welds were continuous. This study therefore resolves itself into a comparison of the buckling behavior of intermittently and continuously supported rectangular plates.

BUCKLING THEORY FOR CONTINUOUSLY SUPPORTED RECTANGULAR PLATES

The buckling of rectangular plates subjected to a uniform compression on both ends was first studied by Bryan[1]. Bryan's formulas were subsequently extended by Timoshenko and others.

The solutions summarized below by Equation 1 are all for relatively long rectangular plates of length *a*, unsupported width *b* and thickness *t*. The ends are considered to be simply supported and acted upon by a uniformly distributed compressive load. The long edges are not loaded by forces in the plane of the plate, but are supported continuously in various manners as noted below. It is assumed that the material is homogeneous and elastic, and follows Hooke's Law; that the plate is free from initial curvature or eccentricities; and that the deflections are small. In such a case, Bryan's formula for the general case is

$$\sigma_{cr} = K \frac{\pi^2 E t^2}{12(1-\nu^2)b^2} \qquad (1)$$

where

σ_{cr} = intensity of axial load at which buckling occurs, also average axial stress caused by the buckling load (called critical stress).
K = a constant depending on the type of support along the long sides.
E = modulus of elasticity in compression.
ν = Poisson's ratio.

The values of K for a rectangular plate having a *length four or more times its width* are as follows, to the nearest tenth:

Both sides clamped	$K = 7.0$
Both sides simply supported	$K = 4.0$
One side clamped, one free	$K = 1.3$
One side simply supported, one free	$K = 0.5$

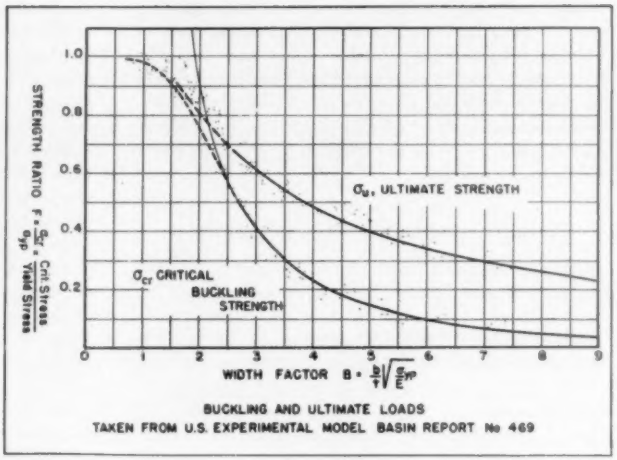

Figure 2

Experiments show that all plates except those having a very low width-thickness ratio buckle at compressive stresses less than the yield point. Theoretical critical stresses in excess of the yield point are therefore meaningless. Strictly speaking Bryan's formula is not valid, however, for stresses which exceed the proportional limit and gives exaggerated values for the critical stress if applied beyond this point. For a plate with simply supported sides and fabricated from average structural steel stock, Bryan's formula would not be applicable, therefore, if the b/t ratio were less than 65, approximately. Several methods have been suggested for approximating the critical stress of plates in the b/t range where buckling occurs at stresses somewhere between the proportional limit and yield point of the material. Among these is the method suggested by Bleich.[4]

REVIEW OF PREVIOUS EXPERIMENTAL INVESTIGATIONS

There have been many excellent investigations dealing with the problem of rectangular plates acted upon by end compressions—for example, references 3–7, and many excellent papers published by the National Advisory Committee on Aeronautics. Apparently all of this research has involved plates one or both edges of which were *continuously* supported, and no research has been done on the case of intermittent edge support such as is encountered in members the elements of which are connected by intermittent welds.

Typical of the results of previous research is Fig. 3 on page 4 of reference 6, which has been reproduced and shown as Fig. 2 herein. This curve gives results for a rectangluar plate simply supported on the two long edges. The heavy solid-line portion of the lower curve (labeled "critical buckling strength") and the light-line extension of it are actually a plot of Equation 1, the Bryan formula, for the case where the two long sides are simply supported, i.e., $K = 4.0$. The tests agreed very well with this curve up to about 70% of the yield point stress. At higher stresses, however, the Bryan formula gives values higher that those observed, because the proportional limit of the material has been exceeded. The dashed-line portion of this curve is a correction to the Bryan curve of the type suggested by Bleich,[7] and checks quite satisfactorily with the limited number of tests in this range. The reduction in the σ_{cr} given by this portion of this curve is, of course, similar to that encountered in tests of short columns.

The upper curve in Fig. 2 represents the experimental values of the ulitmate strength of these plates. Note that there is considerable difference between the buckling load and ultimate strength of plates having a width factor B greater than 2 (this corresponds to a b/t of 60 for the usual structural carbon steel). The reason for this difference is that buckling near mid-width of such plates is not an immediate cause of failure. What does happen is that upon buckling of this central strip it shirks its share of the load and throws additional load

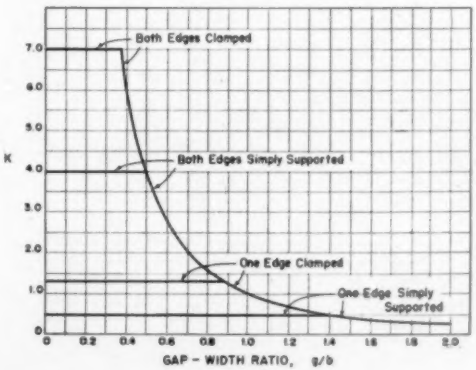

Figure 3

onto the side strips along the two supported edges of the plate. If the stress in the side strip after assuming this additional portion of the load is still less than the yield stress, the total load on the plate may now be increased until the side strips do reach the yield stress.

As a result, if the initial buckling of the plate occurs at a relatively low stress, the ultimate strength of the plate will be considerably greater than the Bryan buckling stress indicated by the lower curve. It must be reiterated that while such local buckling may not cause immediate failure of the plate itself, it might lead to premature buckling of the structural member of which this plate was a component part.

BUCKLING THEORY FOR INTERMITTENTLY SUPPORTED RECTANGULAR PLATES

The following summarizes a rational theory which has been developed to define the buckling behavior of intermittently supported rectangular plates. In this development, consideration will first be given to a theory for an intermittently simply supported rectangular plate, the detailed derivation of which is given in Appendix A.

This derivation is for relatively long rectangular plates which are loaded in their plane by compressive forces on the two ends and intermittently supported along the two long edges as shown in Fig. 14. The ends of the plate are considered to be simply supported and acted upon by a uniformly distributed compressive load. The long edges are not loaded in the plane of the plate and are considered to be simply supported at *points* which are uniformly spaced along the edges. The spacing of these intermittent point supports is called the gap g. The same assumptions are made with regard to the material, initial curvature, eccentricities and deflections of the plate as were made in the derivation of the Bryan formula.

The theoretical value of the critical stress, σ_{cr}, for such a plate may be expressed by Equation 1 where K in this case has the following values:

$$\left.\begin{array}{ll} K = 4.0, & \text{when } 0 < g/b < 0.5 \\ K = (b/g)^2, & \text{when } 0.5 < g/b \end{array}\right\} \qquad (2)$$

where

b = unsupported width of plate.
g* = spacing of, or gap between, intermittent point supports along long sides of the rectangular plate.
g/b = gap-width ratio.

The solution for K given by Equation 2 may be represented graphically as shown in Fig. 3 by the line and curve labeled "both edges simply supported."

If it is recognized that K is equal to 4.0 for a plate supported *continuously* along both long edges by simple supports, and that K is equal to $(b/g)^2$ for a plate acting as a pin-ended column of length g, a very notable conclusion may be drawn from this solution, namely: Up to a gap-width ratio of 0.5, the plate retains the buckling resistance of a continuously supported plate. That is to say, for gaps corresponding to gap-width ratios less than 0.5, the buckling is "plate type buckling," i.e., similar to a continuously supported plate; for gaps corresponding to ratios greater than 0.5, the buckling is "column type buckling," i.e., similar to the plate acting as a pin-ended column of a length equal to the gap. The gap-width ratio at which the buckling changes from plate type to column type is referred to hereinafter as the *critical gap-width ratio*.

The theoretical values of the critical buckling stress for intermittently simply supported plates are summarized in Fig. 4. The solid-line curves give the values obtained by using Equation 1 and the values of K from Equation 2 or Fig. 3. Of course, as in Fig. 2, these curves are not valid and should not be used for critical stresses above the proportional limit. The dashed-line correction curves have been plotted in a manner similar to that done in Fig. 2. In this case, the $g/b = 0$ curve has been corrected by drawing a parabola from the point, $B = 0.5$ and $\sigma_{cr}/\sigma_{yp} = 1.0$, to intersect the solid-line curve at $\sigma_{cr}/\sigma_{yp} = 0.5$. The correction curves for the other gap-width ratios have been drawn so as to be geometrically similar to the first correction curve.

The validity of this correction procedure as well as the adequacy of the theoretical solution may now be investigated by comparing the values obtained from Fig. 4 with the test results obtained in a manner which is described briefly in the next section, as will be shown in Fig. 10.

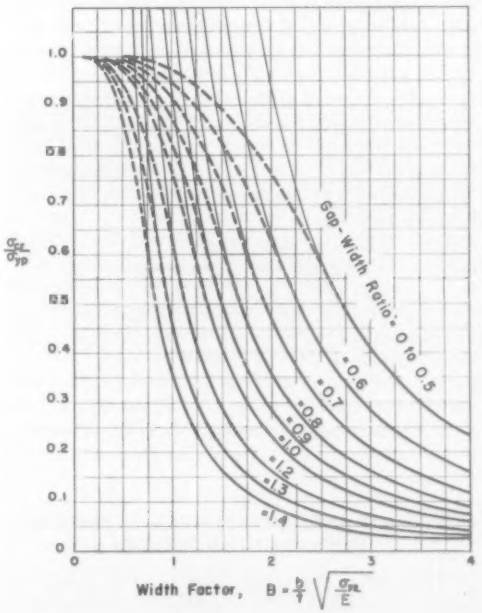

Figure 4

* When Equation 2 is applied to actual plates having intermittent welds of finite length along the edges, the gap g should be considered as the clear distance between intermittent welds.

By proceeding in a manner similar to that described above and in Appendix A, a similar theory has been developed for rectangular plates uniformly compressed on the ends and intermittently supported at equally spaced points along the two long edges by *clamped*, instead of simple, supports. This theory is not presented in detail herein, but leads to the conclusion that the theoretical value of the critical stress, σ_{cr}, for such a plate may be expressed by Equation 1, where K in the clamped case has the following values:

$$\left.\begin{array}{ll} K = 7.0, & \text{when } 0 < g/b < 0.38 \\ K = (b/g)^2, & \text{when } 0.38 < g/b \end{array}\right\} \quad (3)$$

This solution may be represented graphically as shown in Fig. 3 by the line and curve labeled "both edges clamped." It is evident in this case that the buckling changes from plate to column type at a critical gap-width ratio of 0.38. In the same manner as described above, the theoretical values of the critical buckling stress for intermittently clamped plates could be summarized by curves similar to Fig. 4. While such curves are not presented herein, they have been drawn and used to plot the curves shown in Fig. 11 for comparison with test results.

The theory which has been developed for the above two cases suggests the buckling behavior of other types of intermittently supported plates. For example, the value of K for a plate free on one edge and intermittently clamped on the other, or for a plate free on one edge and intermittently simply supported on the other may be obtained by drawing horizontal lines on Fig. 3 at $K = 1.3$ and $K = 0.5$, respectively; that is, at the K values for a continuously supported plate. Thus, the line and curve labeled "one edge clamped" and "one edge simply supported," respectively, define the value of K in each case. It is evident in these cases that the buckling changes from plate to column type at critical gap-width ratios of 0.88 and 1.41, respectively. In these two cases, curves similar to Fig. 4 have been plotted though not presented herein, and values obtained from them have been used to plot the curves shown in Figs. 12 and 13, respectively, for comparison with test results.

A study of the test data tabulated in Appendix B will reveal that plates having the same clear distance between intermittent supports (i.e., the same gap) will sustain essentially the same load regardless of the length of these intermittent supports. In view of this fact, even though this theory has been derived for intermittent *point* supports, it may likewise be applied with confidence to cases where the intermittent support has a finite length equal to or less than the clear distance between supports.

TESTS OF INTERMITTENTLY SUPPORTED RECTANGULAR PLATES

In Phase I of this project, two series of plates were tested. In series A, both long edges of the plate were simply supported; while in Series B, one edge was simply supported and one was free. Phase II was divided into Series C and Series D. In Series C, both edges were clamped; while in Series D, one edge was clamped and one was free. In each of the four series, there were three groups of plates, each having different width-thickness ratios, b/t. In each group, plates were tested with various support arrangements, varying from continuous support to intermittent supports having a gap-width ratio of as much as 2. In the four series, a total of approximately 170 plates were tested.

All tests were conducted in a specially built testing machine having a capacity of 30,000 lb. All of the test plates were approximately 36 in. long and had various widths and thicknesses as noted in Appendix B. In all cases, the test plates were mounted in the machine with their long edges vertical and subjected to a uniform compression on the top and bottom edges. Figure 5 shows a typical plate mounted in the machine and ready to be tested.

In Series A and B, the support along the long edges was provided by a "yoke and channel" arrangement shown in Fig. 6. The "yokes" were circular disks 2 in. in diameter and $^3/_8$ in. thick. A sector of these disks was cut out to form the yoke, which could then be

Figure 5

slipped over the plate and attached to it by setscrews. After the yokes were attached to the plate, a channel was slid over the yokes as shown at the right side in Fig. 6. These channels are the heavy members on each side of the test plate in Fig. 5. The effect of this "yoke-channel" arrangement was to allow an edge of the plate thus supported to move in any direction in the plane of the plate and to rotate about a vertical axis, but did not allow the edge to move perpendicular to the plane of the plate—thereby achieving a simple support. The yokes may be attached as desired along the edge—continuously, or in groups, if an intermittent support were desired, as shown in Fig. 6.

It was intended originally to achieve a clamped support by inserting a key in the keyways on the back side of the yokes. It was found, however, that the edge of the plate could be effectively clamped between two sets of double-ball races such as shown in Fig. 7. These ball races were in turn slid into the same channels as used for the yokes. The plates could be mounted in the ball races in a much shorter time. Tests showed that the ball races provided 75% fixity of the edge, which was close enough to true fixity to demonstrate the effect of clamping on the buckling behavior of intermittently supported plates.

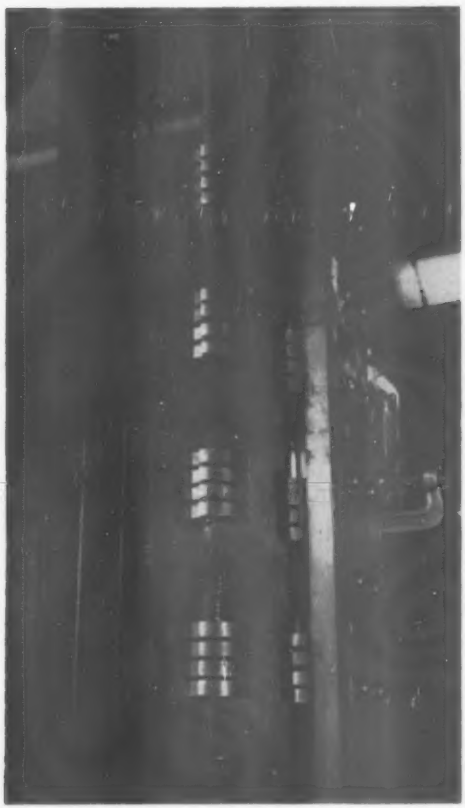

Figure 6

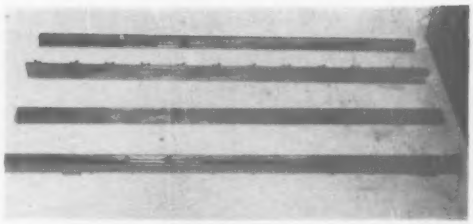

Figure 7

A uniformly distributed end compression was assured by loading a plate through the so-called "flexible knife edge" shown in Fig. 8. Essentially the flexible knife edge is made of three parts: a male and female part, and the plungers. When the male and female part are bolted together they enclose a chamber which is tightly packed with rubber. The plungers pass through the female part and bear against the rubber. Owing to the incompressible quality of the confined rubber, when the plate is loaded through the plungers, the rubber behaves essentially as a high viscosity fluid and applies an equal pressure to all plungers. In this way the ends of the plate are subjected to a uniform compression regardless what the displacement of the edge is.

In these tests, the width-thickness ratios of the plates were low enough so that the critical buckling load and the ultimate load were essentially synonymous. All of the tests were run to the ultimate load and it is that value which will be plotted later. Lateral deflections were measured with dial gages and strains with SR-4 strain gages during the loading of the plate. The number and positions of the strain gages varied, but all plates had at least one pair and some had as many as six pairs.

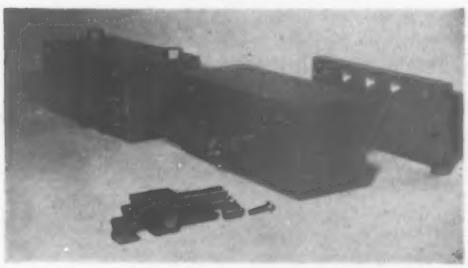

Figure 8

The ultimate loads for plates of the high width-thickness ratios were not difficult to determine since the plates failed with a loud report. For the thicker plates, however, stresses were well beyond the elastic limit before the failure load was reached. In such cases, when the failure load was reached it took at least several minutes, and in a few cases several hours, for the actual

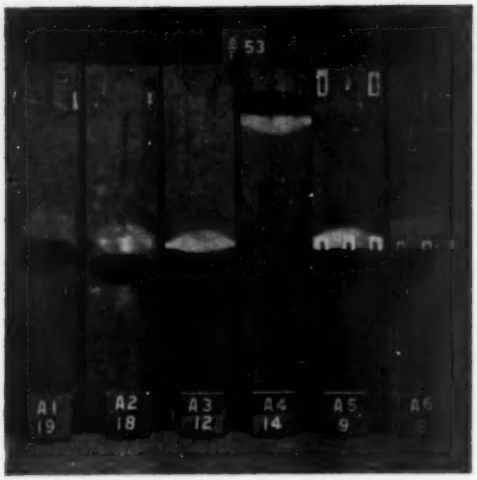

Figure 9

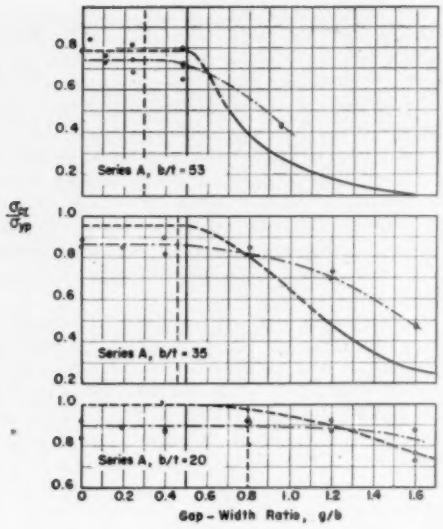

Figure 10

failure to be evident. A typical group of buckled plates is shown in Fig. 9.

COMPARISON OF THEORETICAL AND EXPERIMENTAL RESULTS

All of the pertinent test results for Series A, B, C and D have been tabulated in Appendix B, and the failure stress of each plate of these four series has been plotted as shown by the encircled points in Figs. 10, 12, 11 and 13, respectively. The dot-dash curves shown in these figures have been faired through the test points. The partially dashed- and partially solid-line curves, however, represent the results of the theoretical solution discussed above. The curves in Fig. 10 are a cross plot of the curves in Fig. 4 and represent the ordinates of the latter curves at the following B values:

For b/t = 53 group, B = 1.94
For b/t = 32 group, B = 1.17
For b/t = 20 group, B = 0.63

Curves similar to Fig. 4 were plotted for Series B, C and D and used as a basis for drawing the curves shown in Figs. 12, 11 and 13. Portions of the curves in Figs. 10, 11, 12 and 13 are shown by dashed lines to indicate that the data for plotting those portions came from the dashed-line portions of the Fig. 4 type curves.

Heavy solid vertical lines have been drawn on these graphs at the theoretical value of the critical gap-width ratio. Heavy dashed vertical lines have been drawn at the gap-width ratio which corresponds to a gap which is 16 times the thickness of the plate—that is the maximum gap allowed by most specifications.

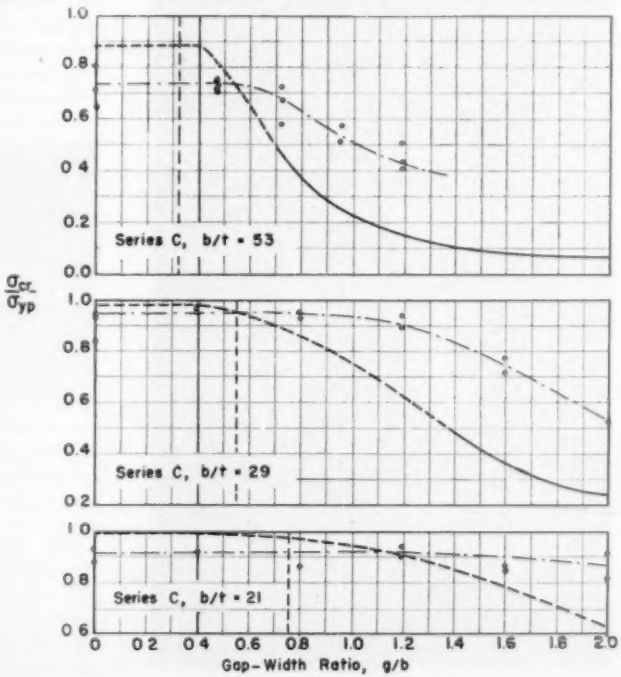

Figure 11

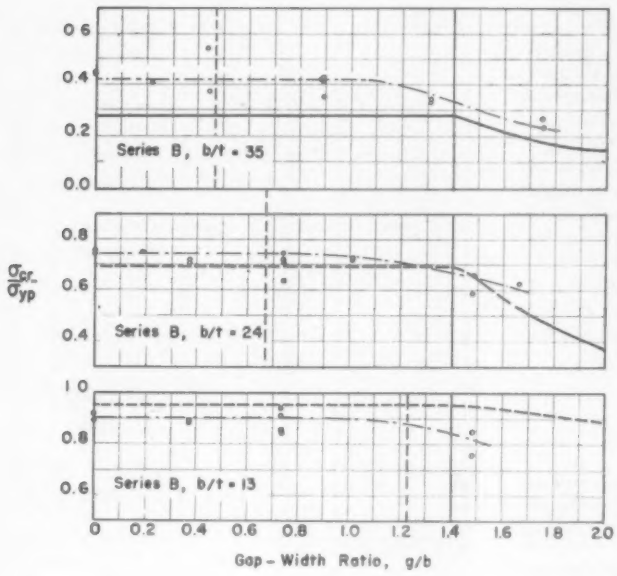

Figure 12

	Critical gap-width ratio
Both edges clamped	0.4
Both edges simply supported	0.5
One edge clamped	0.9
One edge simply supported	1.4

ommendations for specifications to govern the use of intermittent welds cannot be made. It is of interest, however, to compare the results of Series A, B, C and D with present specifications. As noted earlier, the maximum gap allowed by most specifications is represented by the heavy dashed vertical lines in Figs. 10 to 13, inclusive. In none of the twelve graphs has there been a marked reduction in the buckling resistance up to these lines. It is true that in the low width-thickness ratio groups, these lines represent gaps in excess of the critical gap-width ratio. For such cases, however, the buckling resistance decreases very slowly as the gap increases, and, therefore, gaps in excess of the critical gap-width ratio can be tolerated. In view of this fact, it appears that specification writers have been wise in choosing to express the maximum gap in terms of plate thickness rather than gap-width ratio, even though the latter is a more reasonable parameter to use from a theoretical standpoint.

CONCLUSIONS

It is significant to note that the experimental curves are essentially straight and horizontal up to the vicinity of the theoretical critical gap-width ratio and then break down to the right. It is true, of course, that the ordinates of the theoretical and experimental curves do not agree too well in most cases. Close agreement cannot be expected, however, since the ultimate buckling strength depends upon imperfections in the plate, initial curvature, length of intermittent supports, etc., none of which are taken into consideration in the theory developed herein.

The primary objective of the theoretical development was to determine if there was some critical gap-width ratio below which an intermittently supported plate retains essentially all the buckling strength of a continuously supported plate. It is believed that the tests do confirm the buckling behavior predicted by the theory and show that the theoretical critical gap-width ratios are quite accurate. To the nearest tenth, the theoretical critical gap-width ratios are at the top of the next column.

Until Phases III and IV of this program have been completed, definite rec-

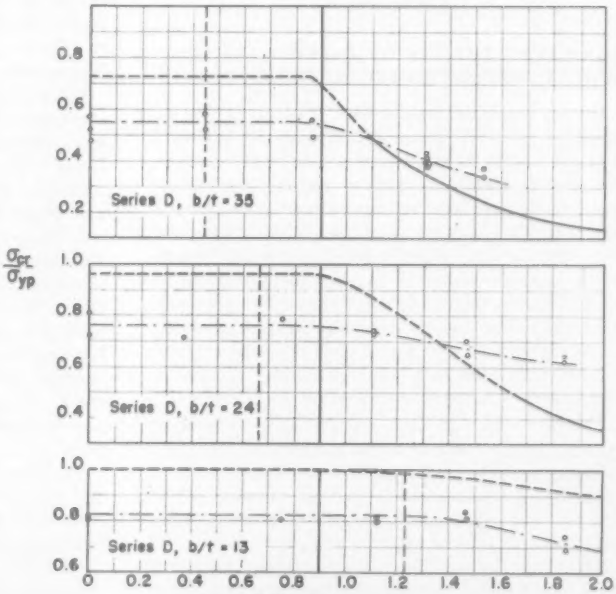

Figure 13

ACKNOWLEDGMENTS

We acknowledge with sincere appreciation the support, guidance and assistance of W. Spraragen, Director of the Welding Research Council, and LaMotte Grover, Chairman of the Structural Steel Committee. To Oliver G. Julian, Chairman of the M.I.T. Project Subcommittee, we are particularly indebted for his continued enthusiastic support and interest, and for his most valued advice and suggestions. We are likewise indebted to John Vasta for his most helpful and constructive criticism at the start of this program and for his continued interest.

The Carnegie-Illinois Steel Corp. contributed most of the steel plate used in these tests. We are very grateful to L. C. Bibber and W. C. Crook of that company for making the necessary arrangements.

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Appendix A

BUCKLING THEORY OF INTERMITTENTLY SIMPLY SUPPORTED RECTANGULAR PLATES

In the following development, advantage will be taken of two conclusions drawn from experimental evidence. First, in the case of an intermittently supported plate it has been observed that the length of the supported portion is not an important parameter as long as it does not exceed the clear space between supports. Secondly, if a series of plates differing only in their gap-width ratio are tested to buckling failure, it will be found that the type of failure changes very gradually from plate to column-type buckling as the gap-width ratio is increased. (See Fig. 9.) In fact, up to a certain gap-width ratio the plate has retained essentially all the buckling resistance of a continuously supported plate.

Consider therefore an intermittently supported rectangular plate such as shown in Fig. 14. This plate is considered to be simply supported and subjected to a uniform compression on the top and bottom edges. The two long edges of the plate, however, are unloaded but supported intermittently. It is convenient in the following derivation to consider the edges simply supported at uniformly spaced points and this appears to be permissible according to the first observation noted in the previous paragraph.

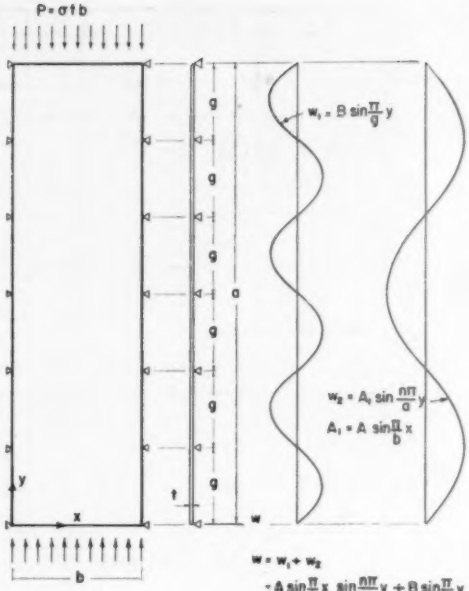

Figure 14

The objective of this development is not to predict accurately the critical stress of a plate having a certain gap-width ratio, but to determine if there is some critical gap-width ratio below which a plate retains essentially all the buckling strength of a continuously supported plate. In view of this, the energy method approach is an adequate, if not necessary, tool for making the following derivation.

Using this approach it is assumed that the plate is acted upon by the end compressions and then some small lateral bending is imposed on the plate. This imposed displacement normal to the plane of the plate is denoted by w and must be consistent with the given boundary conditions. As a result of this lateral bending, bending strain energy will be stored in the plate and, due to the movement of the ends of the plate associated with this lateral bending, the compressions on the ends will do a corresponding amount of work. If the work done by these compressions is smaller than the bending-strain energy for every possible shape of lateral bending, the flat form of equilibrium of the plate is stable. If, however, the work done by the compressions is larger than the bending-strain energy, the flat form of the plate is unstable and it will remain in the buckled position. The critical or buckling value of the end compressions is therefore the value for which the work done by the end compressions, ΔT, is equal to bending-strain energy, ΔV. Using the energy approach, the more accurate the assumed buckled shape, the more accurate will be the value determined for the buckling load.

Assume in this case that the buckled shape of the plate

is the superposition of a plate and column type of buckling; or that

$$w = A \sin \frac{\pi x}{b} \sin \frac{n\pi y}{a} + B \sin \frac{\pi y}{g} \qquad \text{(a)}$$

where A and B are arbitrary constants and n is an integer. Note that this assumed lateral bending satisfies the boundary conditions at all four edges of the plate.

Referring to Timoshenko[2] ΔT may be evaluated from the following expression:

$$\Delta T = \frac{\sigma t}{2} \int\int \left(\frac{\partial w}{\partial y}\right)^2 dx\, dy \qquad \text{(b)}$$

By substituting the first partial derivative of w with respect to y, as obtained from (a), into (b) and integrating, it is found that

$$\Delta T = \frac{\sigma t a b \pi^2}{8}\left[A^2\left(\frac{n}{a}\right)^2 + 2B^2\left(\frac{1}{g}\right)^2\right] \qquad \text{(c)}$$

provided n is not equal to a/g (and in none of the cases to which the final results are applicable would this be true). Note of course that both n and a/g are integers.

Likewise ΔV may be evaluated from the following expression:

$$\Delta V = \frac{Et^3}{24(1-\nu^2)} \int\int \left\{\left[\frac{\partial^2 w}{\partial x^2} + \frac{\partial^2 w}{\partial y^2}\right]^2 - 2(1-\nu)\left[\frac{\partial^2 w}{\partial x^2}\frac{\partial^2 w}{\partial y^2} - \left(\frac{\partial^2 w}{\partial x\, \partial y}\right)^2\right]\right\} dx\, dy \qquad \text{(d)}$$

Again by substituting the proper partial derivatives of w obtained from (a) into (d) and integrating, it is found that

$$\Delta V = \frac{\pi^4 E t^3 a b}{24(1-\nu^2)}\left\{\frac{A^2}{4}\left[\left(\frac{1}{b}\right)^2 + \left(\frac{n}{a}\right)^2\right]^2 + \frac{B^2}{2}\left(\frac{1}{g}\right)^4\right\} \qquad \text{(e)}$$

again provided that n is not equal to a/g.

According to the energy method, however, at the buckling value of the end compressions, $\Delta T = \Delta V$. Therefore, equating the right-hand sides of (c) and (e) and solving for σ, which in this case is the critical stress σ_{cr},

$$\sigma_{cr} = \frac{Et^2\pi^2}{12(1-\nu^2)} \frac{\left\{A^2\left[\left(\frac{1}{b}\right)^2 + \left(\frac{n}{a}\right)^2\right]^2 + 2B^2\left(\frac{1}{g}\right)^4\right\}}{\left[A^2\left(\frac{n}{a}\right)^2 + 2B^2\left(\frac{1}{g}\right)^2\right]} \qquad \text{(f)}$$

Equation (f) may be rewritten as follows:

$$\sigma_{cr} = K \frac{\pi^2 E t^2}{12(1-\nu^2)b^2} \qquad \text{(g)}$$

where,

$$K = \frac{\left[1 + n^2\left(\frac{b}{a}\right)^2\right]^2 + 2\left(\frac{B}{A}\right)^2\left(\frac{b}{g}\right)^4}{n^2\left(\frac{b}{a}\right)^2 + 2\left(\frac{B}{A}\right)^2\left(\frac{b}{g}\right)^2} \qquad \text{(h)}$$

The minimum value of σ_{cr} will be obtained by minimizing K both with respect to $\frac{B}{A}$ and n. When this is done, it is found that the minimizing conditions are that $\frac{B}{A}$ be equal to either 0 or infinity. These conditions correspond, respectively, to either plate- or column-type buckling, and Equation (h) yields, respectively, either $K = 4.0$ or $K = \left(\frac{b}{g}\right)^2$. Obviously, these two solutions for K are identical when $\frac{g}{b} = 0.5$. Below this value of $\frac{g}{b}$, $K = 4.0$ is the true minimum, whereas above it the minimum is $K = \left(\frac{b}{g}\right)^2$. To summarize, the critical stress σ_{cr} is given by Equation (g) where,

$$\begin{aligned} K &= 4.0, \quad \text{when } 0 < g/b < 0.5 \\ K &= (b/g)^2, \quad \text{when } 0.5 < g/b \end{aligned} \qquad \text{(i)}$$

Appendix B

TEST DATA

Table 1—Series A, Both Long Edges Simply Supported

Test No.	Thickness t, in.	Gap g, in.	Support length, in.	Av. stress ultimate load, ksi.
b = 6.25 in.; E = 30,500 ksi.; yield point = 41.0 ksi.				
17	0.118	0	Cont.	32.13
19	0.114	0	Cont.	32.36
16	0.117	0.75	1.5	31.17
18	0.115	0.75	1.5	29.64
11	0.120	1.5	1.5	27.88
15	0.117	1.5	1.5	33.19
12	0.116	1.5	1.5	30.13
10	0.116	3	1.5	26.23
14	0.116	3	1.5	28.85
13	0.117	3	3	31.96
21	0.119	3	3	32.58
9	0.118	3	3	29.24
7	0.116	6	3	17.45
8	0.116	6	3	17.85
20	0.121	4.5	3	24.41
83	0.118	0	Cont.	32.51
b = 3.75 in.; E = 30,500 ksi.; yield point = 41.0 ksi.				
29	0.115	0	Cont.	35.03
24	0.116	0	Cont.	36.32
26	0.115	0.75	1.5	34.99
30	0.117	1.5	1.5	36.61
23	0.116	1.5	1.5	33.41
31	0.117	3	1.5	33.05
22	0.118	3	1.5	33.04
28	0.118	3	3	34.34
25	0.118	3	3	33.16
32	0.116	4.5	3	29.90
27	0.115	4.5	3	28.30
34	0.116	6	3	19.37
21	0.117	6	3	19.20
b = 3.75 in.; E = 30,500 ksi.; yield point = 29.8 ksi.				
35	0.185	0	Cont.	25.13
47	0.186	0	Cont.	27.38
39	0.183	0.75	1.5	26.39
38	0.185	1.5	1.5	25.98
36	0.186	1.5	1.5	25.81
37	0.184	3	1.5	23.66
45	0.184	3	1.5	27.35
44	0.186	3	3	27.45
40	0.184	3	3	27.64
46	0.184	4.5	3	25.83
42	0.185	4.5	3	27.49
43	0.185	6	3	21.75
41	0.184	6	3	22.70
78	0.183	6	3	26.15
76	0.183	5.25	3	25.07
77	0.185	7.5	3	24.44
79	0.183	10.5	3	16.39

Table 2—Series B, One Long Edge Simply Supported; One Free

Test No.	Thickness t, in.	Gap g, in.	Support length, in.	Av. stress ultimate load, ksi.
b = 3.75 in.; E = 30,000 ksi.; yield point = 40.6 ksi.				
61	0.097	0	Cont.	17.84
64	0.094	0	Cont.	17.72
67	0.095	0.75	1.5	16.27
62	0.097	1.5	1.5	14.90
69	0.095	1.5	1.5	16.46
68	0.096	3	1.5	16.30
66	0.096	3	1.5	14.25
63	0.097	3	3	17.12
71	0.096	3	3	16.60
70	0.093	4.5	3	14.04
73	0.094	4.5	3	13.79
72	0.095	6	3	9.65
65	0.095	6	3	10.86
74	0.094	7.5	3	6.69
b = 4.375 in.; E = 30,500 ksi.; yield point = 33.0 ksi.				
48	0.168	0	Cont.	24.71
60	0.167	0	Cont.	24.65
51	0.167	0.75	1.5	24.64
57	0.166	1.5	1.5	23.55
53	0.168	1.5	1.5	23.27
49	0.161	3	1.5	24.69
50	0.169	3	1.5	20.79
56	0.165	3	3	23.19
52	0.168	3	3	23.63
58	0.165	4.5	3	23.69
54	0.164	4.5	3	24.08
b = 4.375 in.; E = 30,800 ksi.; yield point = 27.8 ksi.				
87	0.307	0	Cont.	25.70
89	0.308	0	Cont.	24.81
92	0.309	1.5	1.5	24.74
90	0.310	1.5	1.5	24.41
95	0.310	3	1.5	26.12
96	0.310	3	1.5	23.60
88	0.310	3	3	23.20
93	0.310	3	3	25.26
91	0.309	6	3	23.67
94	0.309	6	3	22.34

Table 3—Series C, Both Long Edges Clamped

Test No.	Thickness t, in.	Gap g, in.	Support length, in.	Av. stress ultimate load, ksi.
b = 6.25 in.; E = 31,400 ksi.; yield point = 41.4 ksi.				
111	0.122	0	Cont.	30.09
112	0.118	0	Cont.	27.73
113	0.121	0	Cont.	34.24
119	0.120	3	0.75	30.81
120	0.132	3	0.75	30.78
117	0.117	3	1.5	31.33
118	0.121	3	1.5	30.34
114	0.118	3	3	30.00
115	0.120	3	3	30.55
116	0.121	4.5	3	28.06
121	0.130	4.5	3	29.84
122	0.131	6	3	23.42
123	0.115	6	3	21.56
124	0.118	7.5	3	17.02
125	0.130	7.5	3	20.62
126	0.119	7.5	3	17.87
184	0.132	4.5	Point	23.80
185	0.117	4.5	3	27.23
b = 3.75 in.; E = 31,500 ksi.; yield point = 40.6 ksi.				
127	0.132	0	Cont.	34.38
128	0.132	0	Cont.	39.05
129	0.132	0	Cont.	38.74
130	0.131	1.5	3	40.11
131	0.131	1.5	3	39.01
132	0.131	3	3	39.32
133	0.131	3	3	38.07
134	0.132	4.5	3	38.71
135	0.132	4.5	3	36.53
136	0.130	6	3	29.18
137	0.131	6	3	31.47
138	0.132	7.5	3	21.16
139	0.132	7.5	3	21.10
b = 3.75 in.; E = 30,100 ksi.; yield point = 30.1 ksi.				
140	0.186	0	Cont.	26.48
141	0.187	0	Cont.	28.32
142	0.187	1.5	3	27.66
143	0.187	3	3	25.79
144	0.185	4.5	3	27.06
145	0.187	4.5	3	27.99
146	0.187	6	3	25.46
147	0.186	6	3	25.93
148	0.187	7.5	3	24.47
149	0.186	7.5	3	27.58

Table 4—Series D, One Long Edge Clamped; One Free

Test No.	Thickness t, in.	Gap g, in.	Support length, in.	Av. stress ultimate load, ksi.
b = 3.4375 in.; E = 31,400 ksi.; yield point = 40.4 ksi.				
150	0.096	0	Cont.	23.10
151	0.095	0	Cont.	18.79
152	0.098	0	Cont.	20.67
159	0.099	1.5	3	21.91
160	0.099	1.5	3	24.09
161	0.095	3	3	22.08
162	0.096	3	3	20.00
157	0.097	4.5	1.5	15.93
158	0.097	4.5	1.5	15.68
153	0.098	4.5	3	17.49
154	0.096	4.5	3	16.75
155	0.096	4.5	4.5	16.35
156	0.097	4.5	4.5	15.68
163	0.096	5.25	3	13.60
164	0.097	5.25	3	14.45
b = 4.0625 in.; E = 30,800 ksi.; yield point = 35.1 ksi.				
165	0.168	0	Cont.	25.52
166	0.168	0	Cont.	28.21
167	0.168	1.5	3	24.91
168	0.170	3	3	27.52
169	0.170	4.5	3	24.97
170	0.170	4.5	3	25.70
171	0.170	6	3	22.07
172	0.170	6	3	24.61
173	0.170	7.5	3	18.25
174	0.170	7.5	3	18.80
b = 4.0625 in.; E = 30,700 ksi.; yield point = 27.4 ksi.				
175	0.311	0	Cont.	21.79
176	0.311	0	Cont.	21.86
177	0.310	3	3	21.92
178	0.311	4.5	3	22.12
179	0.311	4.5	3	22.12
180	0.311	6	3	21.79
181	0.311	6	3	22.38
182	0.310	7.5	3	20.20
183	0.311	7.5	3	18.52

Nested Electrodes for Metal-Arc Welding

The nested electrode consists of two or more filler metal rods nested together but insulated from each other except at the end where they are gripped by the electrode holder; at this point they are connected to each other or to a common source of current

by William A. Snyder

THE process of joining metallic alloys by the metal arc, in its present state, is efficient and produces sound joints. A good process, however, provides the incentive to improve it. Prof. Gilbert S. Schaller of the Department of Mechanical Engineering at the University of Washington has for many years carried out a program to improve the metal-arc welding process. In participating in this program, the author conceived the use of nested electrodes for metal-arc welding. The results of a preliminary investigation of nested electrodes are presented in this paper.

The nested electrode consist of two or more filler metal rods nested together but insulated from each other except at the end where they are gripped by the electrode holder; at this point they are connected to each other or to a common source of current. The electrodes could be manufactured for this purpose with the extruded coating insulating the core wires from each other. It is also possible to use heavily coated electrodes now available with a special electrode holder to grip the electrodes in the desired pattern and provide the common connection. The coatings now in use provide suitable insulation.

In use, the nested electrode offers parallel circuits for current flow. The current will follow the path of least resistance. The welding arc will occur from only one electrode; during the arcing period the electrode temperature will rise increasing the electrical resistance. Burnoff occurs only at the arcing electrode, so as welding progresses the idle electrodes approach the base metal and present the possibility of a shorter arc. The atmosphere surrounding the active arc is ionized so the arc may switch to an adjacent electrode without that electrode making actual contact with the base metal. The rapidity with which the arc switches from one core wire to another may be controlled by the arc length and current setting. High amperage may be used since each conductor has an arcing period and a cooling period. The shape of the puddle may be controlled by the pattern in which the core wires are nested. A short arc is possible because the arc occurs from a small electrode.

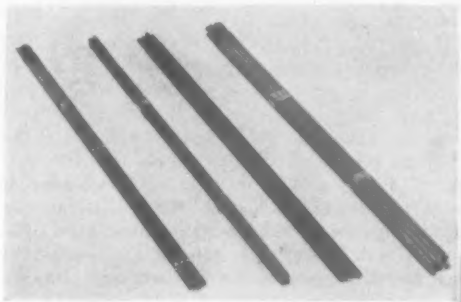

Fig. 1 Nested electrodes

This investigation was limited to $^1/_8$-in. diameter core wires. Larger wires were used with satisfactory results but due to equipment limitations no serious study was made with the larger electrodes. It was convenient to fabricate the electrodes used in this work from standard electrodes. The electrodes were nested in the desired pattern and welded together at one end. Transparent tape which was used to hold the nested electrodes together prior to welding was not removed since it did not appear to effect the arc. A few of the nested electrodes used are shown in Fig. 1.

To simplify the presentation of data, number designations are applied to the various patterns used. If three electrodes are nested in a line and the electrodes are used so a line drawn through the centers of the electrodes is perpendicular to the direction of welding, it is designated as Arrangement 3. If, however, the line of centers is parallel to the direction of welding, it will be Arrangement 1-1-1. If three electrodes are nested so lines connecting their centers form an equilateral triangle, they may be used as Arrangement 1-2 or Arrangement 2-1. A few of the patterns used are shown by Fig. 2.

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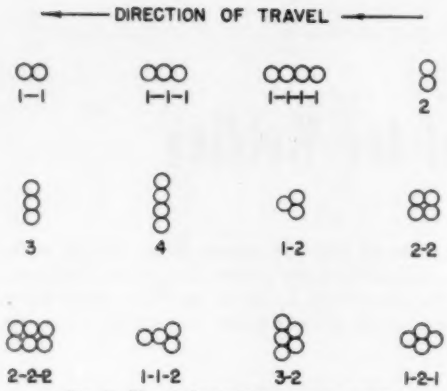


Fig. 2 Electrode nesting arrangements

Three types of welding arcs were employed in the tests. The first was the regular arc in which the arc length was similar to that normally used with $^1/_8$-in. electrodes. The second was the contact arc in which the electrode was held directly against the parent metal, the arc length being maintained by unfused electrode coating. The third method, for lack of a better name, is called "modified fire cracker" or "MF." In this process a contact arc is used with the rod held at an angle. The only action on the part of the operator is to maintain the angle and the contact arc; he does not provide forward movement. The rate of travel is determined by the angle of the electrode and the burnoff rate. In most of the specimens prepared by this method the angle was approximately 45 degrees.

The electrodes from which the various nested electrodes were fabricated were of the E-60XX series with E-6010, E-6013, E-6016 and E-6020 being used to obtain the data presented here.

Since the purpose of this investigation was to compare electrode patterns, it did not seem necessary to make accurate current determinations; the amperages given refer to machine settings and not actual readings. Only two machines were used for this work; one for a.-c. welding and one for d.-c. welding.

WELDED BEADS

To determine the shape of the puddle, beads were laid on $^1/_4$- x 2-in. hot-rolled mild-steel strips. Figure 3 shows four specimens prepared using E-6010 electrode with a conventional arc length. Specimen 111 is a control specimen using a single electrode with a 100-amp. machine setting. Specimen 121 used two electrodes nested in Arrangement 2 with a machine setting of 100 amp. This bead could not have been made with a lower machine setting; the arc was slow in changing from one electrode to the other resulting in a marked variation of arc length; the puddle formed was very shallow. Specimen 131 was prepared using 3 electrodes nested in line in Arrangement 3. The resulting bead was wide and the depth of penetration was shallow. The 200-amp. setting was great enough to cause very rapid switching of the arc. Examination of the crater shows gas pockets trapped by the freezing metal. During welding, escape of gas from the puddle occurred continuously and although sectioned beads of this type showed no signs of gas porosity, the E-6010 beads were

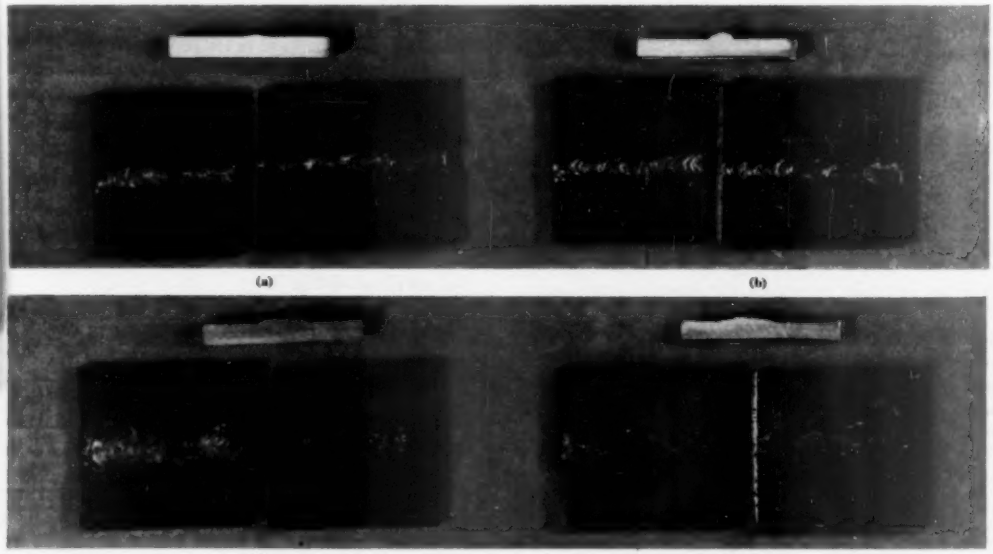
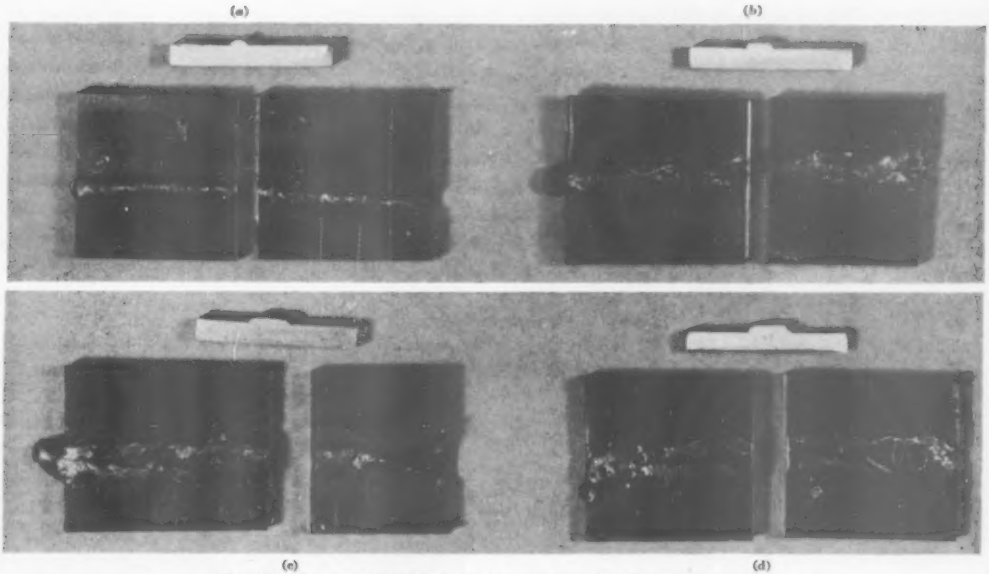


Fig. 3 Weld beads produced from E-6010 electrode nests by conventional arc length

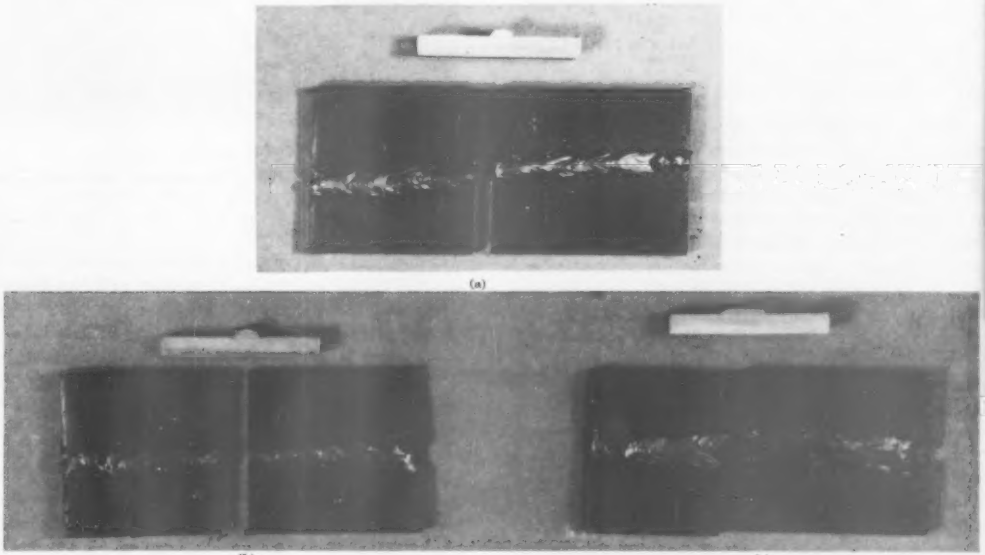


(a) (b) (c) (d)

Fig. 4 Weld beads produced by MF arc from E-6010 electrode nests

susceptible to center-line cracking and probably to underbead cracking. Specimen 143 was made with four $^1/_8$-in. electrodes nested in Arrangement 4 using a machine setting of 225 amp. This bead was, of course, wider than 131 but was similar in other respects. Spatter was less because the average current density was lower. All of these beads except 121 were very flat and contoured smoothly into the parent plate. Specimen 121 made with the low average current density of 4070 amp. per square inch of electrode cross section showed a high bead; a long arc was necessary to avoid sticking. When four electrodes were used, as in Specimen 143, a very short arc could be held with approximately the same average current density.

Specimens prepared with E-6010 electrodes and MF welding procedure are shown in Fig. 4. Specimen 112



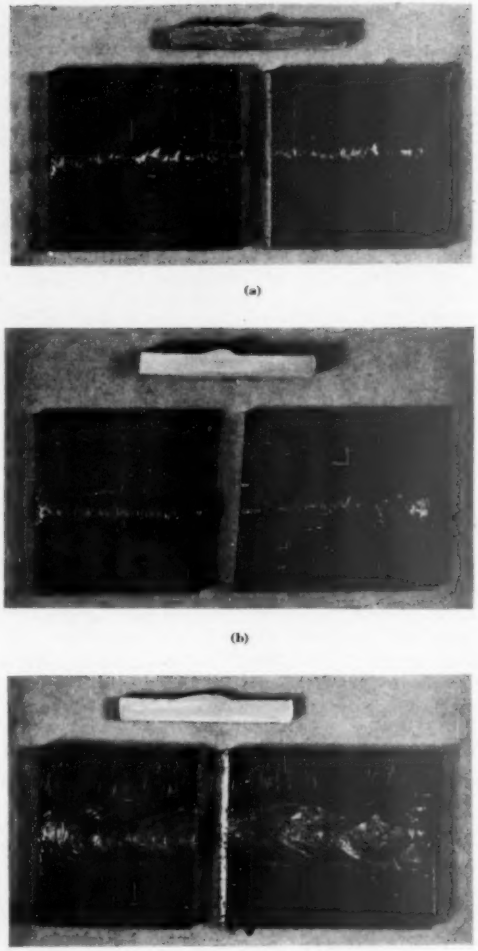
(a) (b) (c)

Fig. 5 Weld beads produced from three E-6010 electrodes arranged in various patterns

was made with a single electrode with a machine setting of 100 amp. It produced a high bead with almost no spatter. Using two electrodes nested in Arrangement 2, Specimen 123 was obtained with a setting of 200 amp. With this electrode, arrangement and procedure, a lower amperage could not be used without sticking. This procedure shows a high bead and undercutting occurring together. Gas porosity is shown in the crater but the weld is sound. Specimen 132 was made with three electrodes nested in Arrangement 3 and a machine setting of 250 amp. The puddle shows rapid evolution of gas and center-line cracking occurred. The bead is very flat coming sharply down to the parent plate at the edge. The capacity of the machine used for this series was not sufficient to produce a bead with Arrangement 4. However, Specimen 142 was produced by using four electrodes nested in Arrangement 2-2. A high flat bead was obtained with visible porosity at the beginning and end of the bead. Sectioned specimens also showed porosity in the weld, illustrating the gas difficulties that can be expected from a compact arrangement of E-6010 electrodes. In general, beads shown in this group are high and flat, a shape useful for metal overlay.

Figure 5 compares the bead shapes that can be obtained using three E-6010 electrodes nested in various patterns. Specimen 136 was produced with electrodes nested in Arrangement 1-1-1 using 150 amp. and a contact arc. The arc was very stable with a low current density because with this arrangement the area of the puddle can be very small and still provide molten metal under each electrode. This procedure produced a high narrow bead similar to that produced by a like procedure with a single electrode. Electrodes in Pattern 1-2 produced Specimen 138 when a contact arc was used with 150 amp. A high, rounded, uniform bead was produced, accompanied by very bad spatter. Specimen 135 used the same arrangement but was made by the modified firecracker technique with 250 amp. A wide flat bead was produced with very little spatter.

Figure 6 presents beads produced with E-6016 electrodes using a d.-c. welding machine. Specimen 411 is a bead that resulted when a single electrode was used in a conventional manner. Specimen 421 was produced with a conventional arc using two electrodes nested in Pattern 2. A machine setting of 100 amp. was used. The arc switched in a slow uniform fashion while this bead was being made. The resulting bead is fairly uniform and contours smoothly into the base metal. Visible porosity is in evidence where the arc was started; other trials showed that this could be eliminated by allowing one electrode to project beyond the others so the arc could not begin to switch until the puddle was well formed. Specimen 431 used three electrodes in Arrangement 3 with a machine setting of 200 amp. A wide smoothly contoured bead was formed with rather shallow penetration; visible porosity may be seen at the beginning of the weld. The bead shapes of this group conform rather closely with the similar group produced with E-6010 electrodes. During welding it



(a)

(b)

(c)

Fig. 6 Weld beads produced from nested E-6016 electrodes

was observed that the metal deposit was more uniform and the molten puddle less deep than with the E-6010 electrode. Porosity is common at the start of the weld unless precautions are taken to prevent it, but there is no indication of gas evolution during welding.

The examples shown in Fig. 7 were made using E-6016 electrodes with MF and contact-arc techniques. Specimen 412 was produced by a single electrode with an MF arc using a machine setting of 100 amp. The result is a high, narrow, uniform bead. A nest of two electrodes in Arrangement 2 was used to prepare Specimen 423. The MF technique was employed with a machine setting of 150 amp. The resulting bead was high and uniform with no visible porosity at the start of the weld.

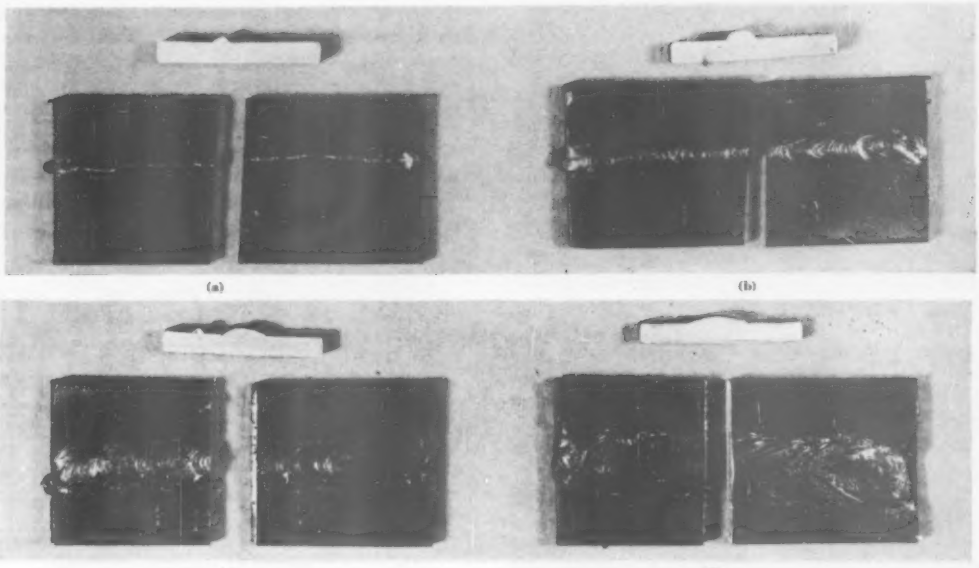


Fig. 7 Beads welded from E-6016 electrode nests using MF arc

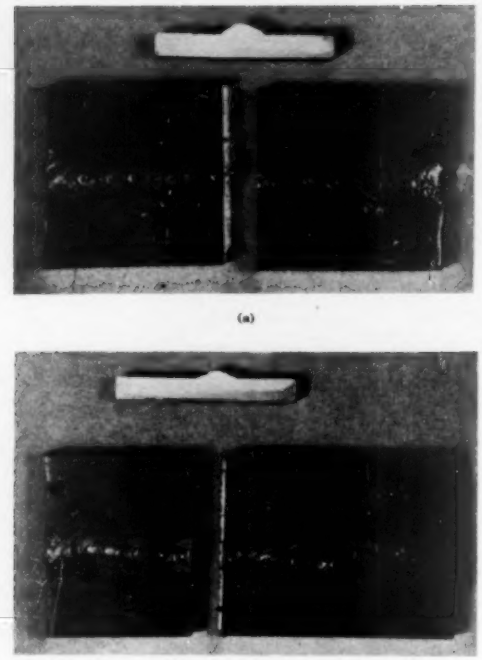
This bead resembled a well-made machine weld and is typical of the uniformity that can be obtained with nested electrodes and the MF arc. Specimen 432 was made with three electrodes nested in Pattern 3 with a machine setting of 225 amp. The contour of this bead is typical of several produced in this manner. However, the bead is irregular because one electrode in the nest did not burn off as rapidly as the rest. Examination of the electrode stub showed that this electrode had a poor electrical connection with others in the nest. Specimen 444 resulted from four electrodes nested in Pattern 4 using a contact arc. The machine setting was 250 amp. This procedure produced a wide smooth bead.

To summarize this group, the beads produced were smooth and uniform. The short arc resulting from the MF process with nested E-6016 electrodes was very stable and metal transfer was uniform. Unlike the previous group there was seldom any visible porosity at the beginning of a weld. There was, however, a tendency to undercut which can be reduced by lowering the current or be eliminated by placing electrodes behind the first row, that is, by using Arrangement 3-1 instead of Arrangement 4.

Figure 8 shows three specimens prepared using four E-6016 electrodes nested in various patterns. The contact arc was used to lay these beads. Specimen 442 was made with Arrangement 2-2; this produced a bead similar to that which would be produced by a single $^1/_4$-in. electrode but made with a shorter arc length than would be possible with the single electrode. The high current density on the first small electrode to arc tends to eliminate the possibility of porosity at the beginning of the weld. Specimen 445 was made with Arrangement 1-1-1-1 and a machine setting of 225 amp. A narrow, pointed bead resulted.

It may be concluded from the foregoing examples that the shape of the puddle, and through this the shape of the weld bead, may be controlled by the pattern in which the electrodes are nested. Metal deposits may be varied from wide flat beads to high narrow beads without materially changing the rate of metal deposit. The self-regulating arc of nested electrodes appears to be very advantageous when welding with a contact arc. As was expected, the E-6010 series of electrodes does not lend itself well to nesting because the conditions are excellent for gas absorption by the metal. Other E-60XX electrodes were tried with the metal deposits being equal or better in appearance than the examples shown of E-6016 deposits. The smoothest and most uniform deposits were obtained with nested E-6020 electrodes.

Penetration was affected by several factors other than the nesting pattern. In general, however, the penetration was less than would be obtained from a single electrode of equal cross-section area. In the case of the wide flat beads, the penetration is greater than would normally be obtained by weaving a similar metal deposit with a single $^1/_8$-in. electrode. No special technique is required on the part of the welder to produce a wide deposit with nested electrodes, and slag will not be trapped unless the machine setting is incorrect.



(a)

(b)

Fig. 8 Weld beads produced from E-6016 electrode nests containing four electrodes in various arrangements

RATE OF METAL DEPOSIT

The rate of electrode burnoff was investigated to determine the effect of nesting on welding speed. The burnoff times were determined by notching test electrodes 1 and 7 in. from the end. The welder laid a bead along the edge of a 1/4 x 2-in. mild-steel strip. The timer started a stop watch at the first notch and stopped it at the second, obtaining the burnoff time for the 6-in. increment. This work was carried out with an a.-c. welding machine with a N.E.M.A. rating of 30 v., 200 amp.

Table 1—Time in Min. to Burn Off 6 In. of 1/8-In. Electrode

Mach. setting, amp.	*1*	*2*	*3*	*4*	*Type of electrode*
100	0.63	1.21	...	...	E-6013
		1.20	...	...	E-6020
150	0.41	0.80	1.17	1.52	E-6013
		0.71	...	1.47	E-6020
200	0.29	0.59	0.88	1.14	E-6013
		0.57	...	1.10	E-6020
250	0.24	0.47	0.72	0.92	E-6013
		0.43	..	0.86	E-6020

Table 1 presents the data obtained from E-6013 and E-6020 electrodes. The first column records the burnoff time of a single 1/8-in. electrode with machine settings of 100, 150, 200 and 250 amp. The second column shows the burnoff time for two 1/8-in. electrodes nested in Arrangement 2. The time tabulated is for a 6-in. increment or a total of 12 in. of electrode. In similar fashion the third and fourth columns show burnoff times for nests containing three and four electrodes. Calculating the rate of metal transfer in inches of electrode per minute shows that the rate of transfer is independent of the number of electrodes nested. Figure 9 shows that within the limits of the test, the rate of

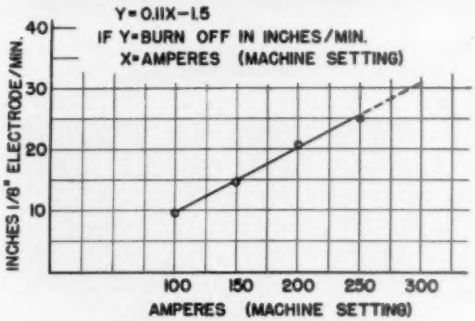


Fig. 9 Electrode burnoff rate

metal transfer has a straight-line relationship with the current setting of this particular machine. From this data the burnoff rate may be calculated from the following formula:

$$y = 0.11\,x - 1.5$$

if

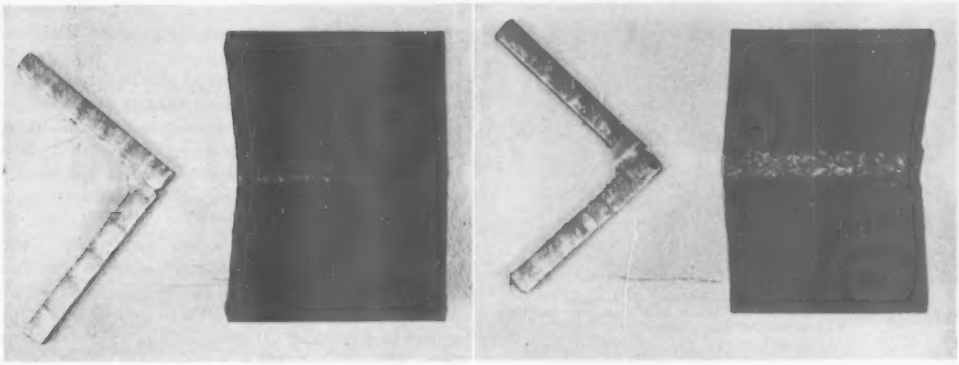
y = burnoff in in. per minute
x = amp. (machine setting)

From the data given it may be shown that if it took 1 min. to weave a wide bead with a single 1/8-in. electrode and a machine setting of 100 amp., a similar deposit could be made with three electrodes nested in Arrangement 3 with a current setting of 200 amp. in 0.46 min. In addition, a bead three times as long could be made with the nested electrode before it was consumed.

WELDED JOINTS

Information gathered from laying beads was applied in producing welded joints. A few typical joints made with an a.-c. welding machine are described here.

Figure 10 shows 1/4-in. fillets made with E-6020 nested electrodes by a contact arc. The parent metal is 1/8 x 2-in. hot-rolled steel. Specimen 521 utilized two electrodes nested in Arrangement 1-1 and a machine setting of 150 amp. This fillet is comparable in all respects to one that could be produced by a single 1/8-in. electrode; however, the use of nested electrodes allows higher current without undue spatter and thereby increases the welding speed. A longer fillet may also be produced before the electrode is consumed. The nested electrode produced 1.1 ft. of weld at the rate of 6 in. per minute. Specimen 534 used three electrodes in Ar-



(a) (b)

Fig. 10 Fillets produced from nested electrodes

rangement 1-1-1. A machine setting of 200 amp. and a contact arc were employed to produce this weld. This nested electrode produced 1.6 ft. of weld at the rate of 8 in. per minute. The resultant fillet has a slightly rougher appearance due to the increased welding speed.

Figure 11 shows two $^1/_4$- x 2-in. strips joined by a $^1/_2$-in. fillet. This type of joint is of no practical value but was used to investigate multipass fillets made with nested electrodes. The electrode nests were made with E-6020 electrodes and a machine setting of 200 amp. was employed for each pass. The original fillet was produced with two electrodes nested in Arrangement 1-1 to insure satisfactory corner penetration. The second pass was made with three electrodes in Arrangement 2-1. The third pass used three electrodes in Arrangement 3 and the final pass used four electrodes in Arrangement 4. In each case the nesting pattern was selected to suit the available working space. The total arc time to produce 1 ft. of weld was 6.6 min. to give an average welding speed of 1.82 in. per minute.

A $^3/_8$-in. fillet joining two $^1/_2$-in. plates is shown in Fig. 12. To weld this joint six E-6020 electrodes were nested in Arrangement 2-2-2. The weld was made in a single pass with a machine setting of 275 amp. A contact arc was easily maintained with this setting. A sound weld was produced at the speed of 4.9 in. per minute. One nested electrode produced more than 1.4 ft. of weld. Similar fillets made with Arrangement 3-3 required 300 amp. to prevent slag inclusion.

Figure 13 presents a butt weld connecting two $^1/_2$-in. plates. The edge preparation gave an included angle of 60 degrees. The plates were tacked together with no root opening or backup. The joint was made in two passes using in each case a nest containing four E-6020 electrodes and a machine setting of 300 amp. The first pass used the electrodes in Arrangement 1-1-1-1 to work in the limited area at the bottom of the V. The second pass used Arrangement 4 to produce a flush

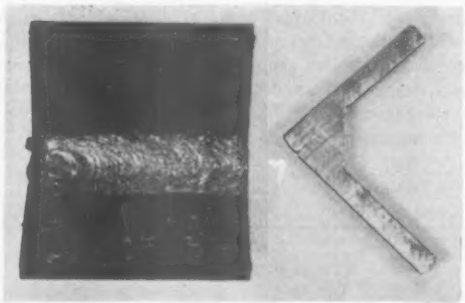


Fig. 11 A multipass fillet produced from nested electrodes

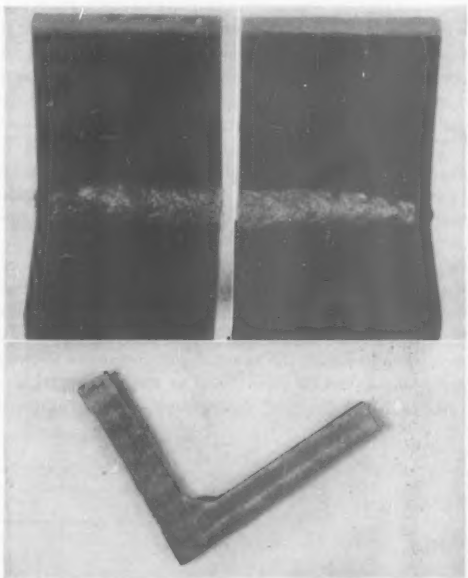


Fig. 12 A $^3/_8$-in. single-pass fillet produced from a nested electrode

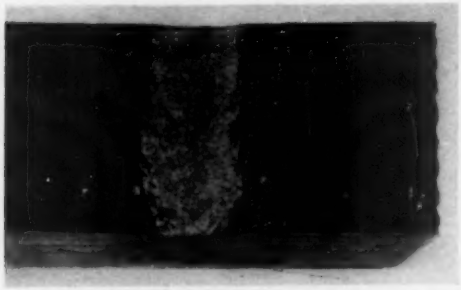


Fig. 13 A butt weld of 1/2-in. plate made in two passes with nested electrodes

joint. When a slight bead is desired the second pass may be made with five electrodes in Arrangement 3-2. The joint shown required a total arc time of approximately 4.5 min. per foot of weld to give an average welding speed of 2.6 in. per minute.

Butt joints made in this manner never showed signs of slag inclusion; however, in some specimens the fusion was incomplete at the beginning of the weld. This can be eliminated by using a light backup strip and a higher average current density on the first pass or a starter plate.

SUMMARY

Satisfactory welds were produced from electrode nests using all classes of electrodes; however, the E-6010 and E-6011 electrodes are not recommended for compact nesting arrangements or for contact-arc welding. The stability of the arc makes the electrode nest desirable for other types of electrodes especially when a contact arc is to be employed. The ease of holding a contact arc is especially valuable when using E-6015 and E-6016 electrodes.

The ability to control the shape of the weld puddle is of considerable interest; it allows a narrow fillet or bead to be made at a high rate of metal transfer. A wide bead may also be produced without weaving at approximately the same rate of transfer. The nest arrangement may be selected to suit the job. In the work with 1/8-in. electrodes it was not found desirable to nest more than four electrodes in line although some welds were made with longer lines. For a given number of electrodes in a nest the compact arrangements allowed a contact arc to be maintained at lower machine settings than the "in line" arrangements. The ability to deposit metal rapidly with a shallow puddle should prove interesting in many applications where dilution of weld metal is not desired.

An interesting development of this research was the fact that when suitable machine settings were employed no trapped slag was found by macroscopic examination even when twelve electrodes were used in a nest. Two factors are probably responsible for this slag-free deposit. First, to operate smoothly the nest must maintain a puddle extending under all of the electrodes in the nest. Second, although the arc may produce very smooth weld deposits it is actually a very violent arc. The average current densities used in these experiments varied from less than 4000 to over 8000 amp. per square inch of electrode cross section. The arc occurs from only one electrode at a time so the actual current density may be obtained by multiplying the average figure by the number of electrodes in the nest. Actual current densities often exceeded 24,000 amp. per square inch of electrode cross section.

The nested electrode offers many intriguing possibilities. The short forceful arc promotes sound weld metal. In manual welding on heavy plates it appears to be evident that the welding cost could be reduced substantially by the correct use of nested electrodes. The nest not only allows rapid metal deposition in restricted space but, since it tends to contour itself to conform to the edge preparation, the number of passes required to complete a weld can be minimized. The leading electrode in the nest arcs to the bottom of the V; the following electrodes may be located to carry the puddle to the sides of the V near the top. By using electrode Arrangement 1-1-2, butt joints in 3/4-in. plate have been completed with single pass.

The stitching arc that may be obtained from Arrangement 1-1 with a low current setting should prove to be of interest for welding stainless steels. The stitching arc was used with Arrangement 2 to deposit a hard-surface overlay on cast-steel test plates. Due to reduced dilution of the weld metal, the hardness of the deposit was as high as would normally be expected on the second pass. The ability to produce a large weld without penetrating deeply into the parent metal should also be useful in welding steel castings.

It appears from this investigation that welding with nested electrodes, due to its unique method of metal deposition, should find useful applications paralleling existing arc welding techniques. The acceptance of this novel development can only be expected where vision and imagination are combined in a pattern of fundamental progress.

Fatigue Tests of Beams in Flexure

Discussion by Ned L. Ashton

This report summarizes the results of extensive fatigue tests conducted by Prof. W. M. Wilson, of the University of Illinois.

To say the least, these tests undoubtedly represent the results of a great deal of work and if the results and conclusions drawn, in this summary, are correct they are the worst rebuke that has ever been handed to the practicing structural engineering profession, in one single package, since the beginning of the century. Therefore because these results are alarming to those who are responsible for the safety of many existing structures and because they tend to undermine the very theory upon which all of our existing structures have been founded, I proceeded to investigate several of the typical tests more thoroughly and I have the following comments which I believe should also be published.

Figure 1 is a review of test beam 44Bd of the Illinois tests for which the authors state: "The capacity of the beam with the full-length cover plate is 116.3 kip. ft. while that for the beam with the partial-length cover plate is only 51.0 kip. ft. indicating that the cutting off of the plate reduced the capacity by 56%."

Figure 1 shows conclusively that the beam was designed so that it was limited by the strength of the beam at point *A*, at the end of the cover plate, without the benefit of any cover plate reinforcement. The actual length of cover plate used was only 65% as long as it should have been to develop the plate in accordance with the laws of statics, to say nothing at all of fatigue.

No account seems to have been taken of the redistribution of flange stresses that takes place, independently of the $dM = V\,dx$ requirements, at any change of sec-

Ned L. Ashton is Consulting Engineer in Iowa City, Iowa.

Paper by E. J. Ruble, Research Staff A.A.R., was published in the March 1951 *Welding Research Supplement*, pp 105-s to 115-s.

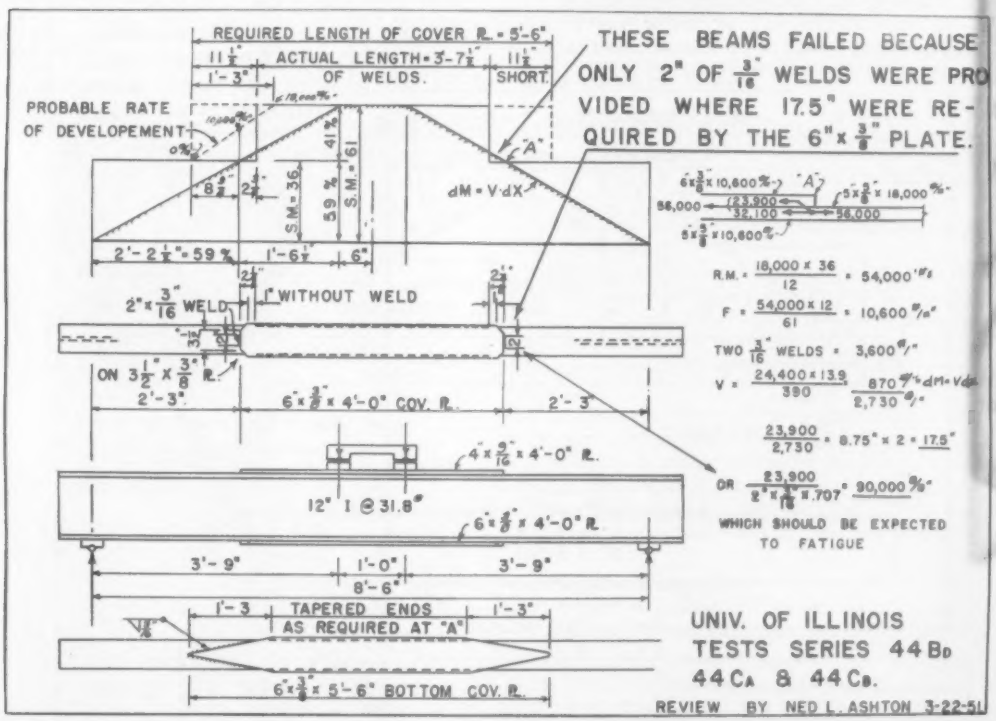

REQUIRED LENGTH OF COVER PL. = 5'-6"
ACTUAL LENGTH = 3'-7½" OF WELDS.
1'-3"
1½" SHORT
PROBABLE RATE OF DEVELOPEMENT
"A"
41 %
59 %
S.M. = 61
S.M. = 36
dM = V·dX
2'-2½" = 59 %
1'-6½"
6"
2" × 3/16" WELD
1" WITHOUT WELD
ON 3½" × 3/8" PL.
2'-3"
6" × 3/8" × 4'-0" COV. PL.
2'-3"
4" × 9/16" × 4'-0" PL.
12" I @ 31.8#
6" × 3/8" × 4'-0" PL.
3'-9"
1'-0"
3'-9"
8'-6"
1'-3
TAPERED ENDS AS REQUIRED AT "A"
1'-3"
1/4"
6" × 3/8" × 5'-6" BOTTOM COV. PL.
THESE BEAMS FAILED BECAUSE ONLY 2" OF 3/16" WELDS WERE PROVIDED WHERE 17.5" WERE REQUIRED BY THE 6" × 3/8" PLATE.
6 × 3/8 × 10,600 %
"A"
5 × 3/8 × 18,000 %
56,000
123,900
32,100
56,000
5 × 3/8 × 10,600 %
R.M. = 18,000 × 36 / 12 = 54,000 "#
F = 54,000 × 12 / 61 = 10,600 #/"
TWO 3/16" WELDS = 3,600 #/"
V = 24,400 × 13.9 / 390 = 870 #/" dM = V dx
2,730 #/"
23,900 / 2,730 = 8.75" × 2 = 17.5"
OR 23,900 / 2" × 3/16" × .707" = 90,000 #/"
WHICH SHOULD BE EXPECTED TO FATIGUE
UNIV. OF ILLINOIS TESTS SERIES 44 Bd 44 Ca & 44 Cb.
REVIEW BY NED L. ASHTON 3-22-51

Figure 1

tion and made no allowance for such action at the ends of their cover plates. This action is entirely independent of the moment curve requirement and requires about 17.5 in. of weld on the beams of tests 44Bd in place of 2-in. fillet welds that were provided extending only partially across the ends of the plates.

Since the 2-in. welds were stressed way above the yield point from the considerations of simple statics, it should have been evident that this high concentration of stress on the end welds was either going to cut the beam in two or else shear the welds that connect the plate to the beam even before the beam was fabricated.

Since the bottom cover plates of series 44Cd and 44Ce were accidentally made long enough and apparently did not fail, because the beams were designed to fail on compression flange, possibly some useful information about the tension flange can be salvaged from the tests of these two particular beams.

Since test beams 44Ga have only 48 in. of $^1/_8$-in. fillet welds between the reaction and the load point and 66 in. of $^1/_8$-in. fillet welds are required to develop a 7 x $^5/_8$-in. flange plate properly, it is natural to expect that only $^{48}/_{66}$ or 73% of the flange could be developed in the test. It certainly does not furnish grounds for any other startling conclusion relative to the strength of a fabricated beam as compared to rolled beams, especially since the beams were deliberately designed, to quote the author: "In an effort to produce fatigue failures in the welds fastening the flange plates to the web, the span length for this series was reduced to 5 ft."

These conclusions should be limited to the purpose for which these beams were designed and general conclusions in regard to the moment capacity of all fabricated beams should not be drawn from tests made on beams that were deliberately designed on a short span to fail in horizontal shear.

Neither should their moment capacity be compared to that of another more flexible rolled beam on a longer span as is done by the authors, in Table 2.

Figure 2 is a review of the author's test beam of series 43E and 44E in which the 12-in. I was reinforced with partial-length riveted cover plates. And again, in this test, I find that the actual cover plate lengths were only 65% as long as they should have been to provide the proper length that is required by most standard specifications for the redistribution of the flange stresses at the ends of the cover plates.

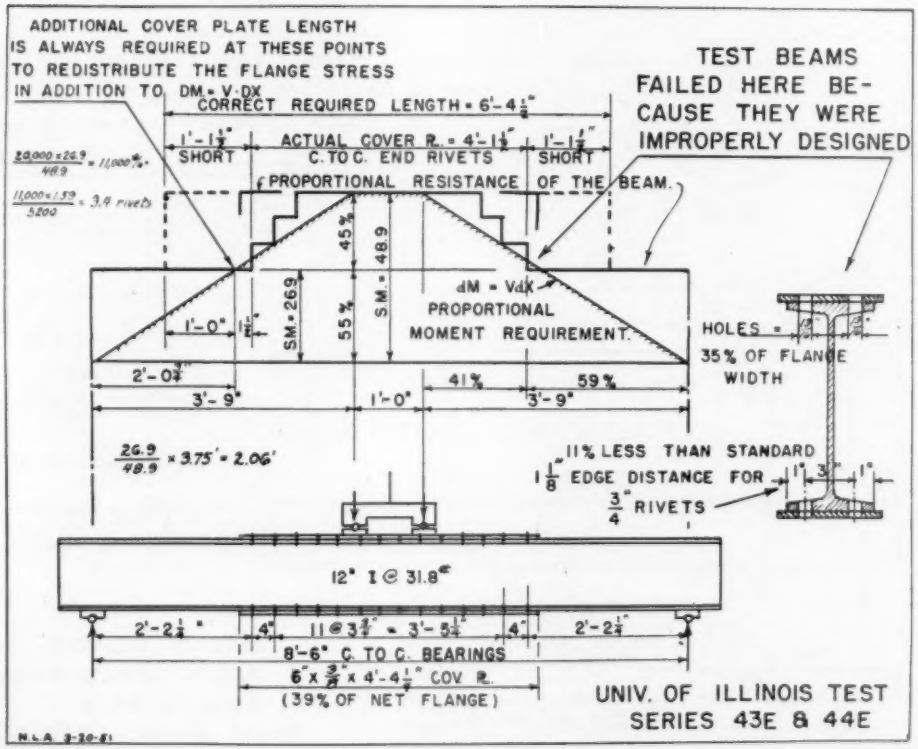


Figure 2

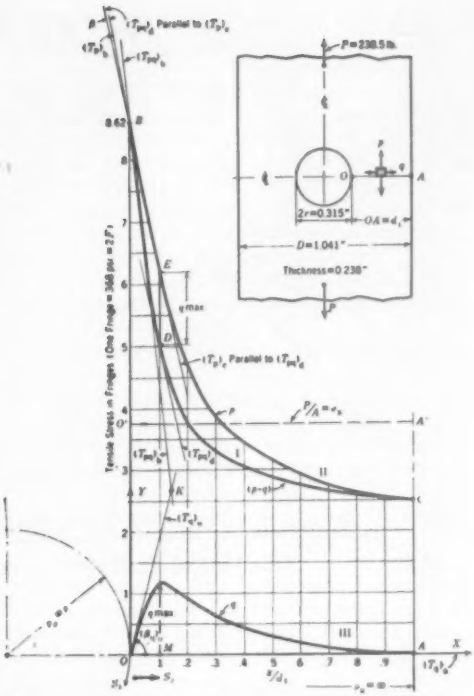


Fig. 3 (a) Distribution of principal stresses across the transverse section of symmetry in a bar with a central circular hole subjected to an axial tension. The (p-q) curve is based on the t_2 stress pattern in Fig. 3 (b)

Fig. 3 (b) Stress pattern of a bar with a central circular hole subjected to an axial tension

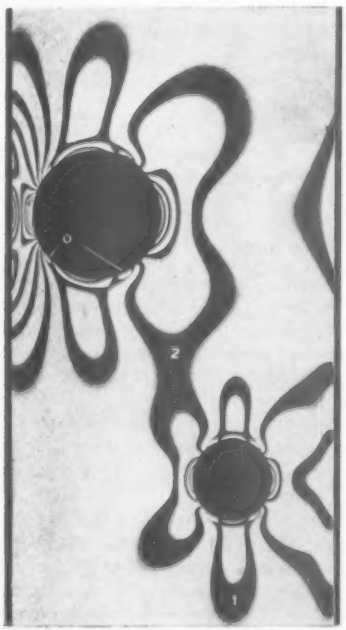


Fig. 4 Stress pattern of a bar containing two eccentrically placed holes and subjected to axial tension. Axial load, 172.7 lb.; thickness, 0.172-in. material fringe value; f, 43 psi. shear stress

In addition to this serious weakness, the maximum possible size flange rivets were used in the 5-in. flanges, with less than the minimum safe edge distance to a rolled edge thus creating a stress condition in which it is somewhat naive to talk about fatigue on the basis of an average stress.

Figure 3 shows the stress situation that exists around a central circular hole that is subjected to tension and Fig. 4 shows how this situation gets worse as the holes are moved over closer to the edges of the I-beam flanges to say nothing of the bursting pressures created during riveting.

Thus the riveted beams also are of faulty design and hence general conclusions cannot be drawn.

It is indeed regretable that much desirable information has been lost in this manner from these tests and yet the stamina that has been demonstrated for the plain rolled beams under this very severe test is remarkable.

All of the so-called fatigue failures seem to be related to very high concentrations of stress that were caused by improper details and they bear no relation whatever

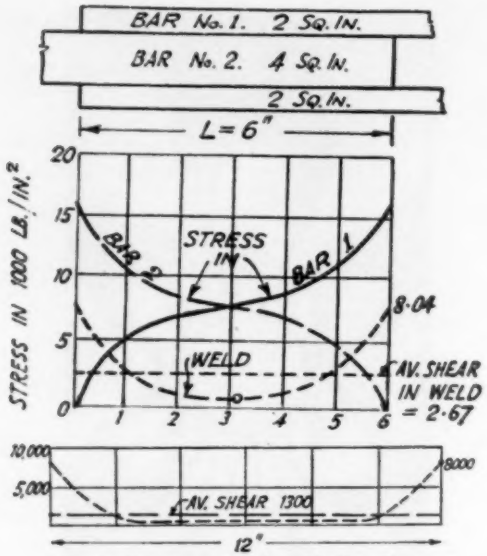


Fig. 5 Shear stress in side welds 12 in. long

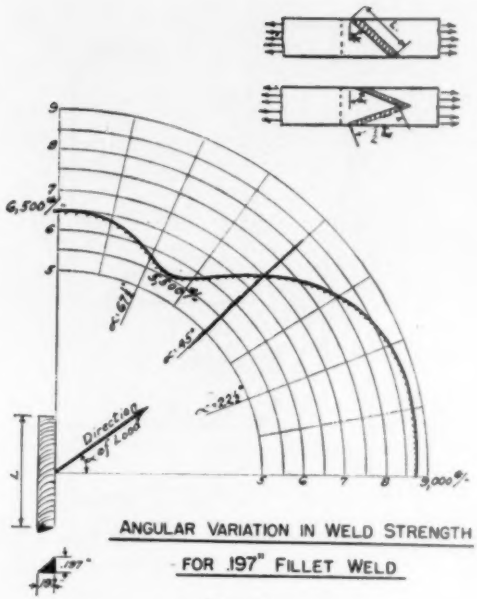


Figure 6

to the published average stresses. Some of the more important of these considerations are illustrated in the following figures. Figure 5 is an interesting British test that shows the relative conditions of stress in the bar straps and welds for two different lengths of redistribution. This test is typical of the situations that were created in the flanges of these beams with the various flange attachments and cover plate reinforcements.

Figure 6 is the result of some French tests that indicate the variations in strength that occur when the welds are loaded in different directions.

The author's tests definitely indicate that all engineers should pay more attention to such details and should use fillet welds cautiously but otherwise our current standard design practices and theories are apparently still sound and our existing structures are still quite safe and in no danger whatever of failing from fatigue, providing only they were properly designed in the first place.

Author's Reply

In reviewing Mr. Ashton's discussion of the report on fatigue tests of beams in flexure, it should first be pointed out that the tests were planned to determine the relative fatigue strength of various types of bridge members subjected to flexure and the fatigue strength of the various details used in fabricating such beams. I, personally, feel that the various types and details selected by the committee are representative of present engineering practice.

The principal criticism of the report pertains to the details used in fabricating the beams with partial length cover plates and Mr. Ashton apparently feels that the plates should be completely developed at the theoretical "cut-off" point. It should first be mentioned that the tests on beams with partial length cover plates were not conducted to determine the fatigue strength of the beam at the point of maximum moment but were made to determine the fatigue strength of the section at the end of the cover plate. In discussing the length of cover plates it was common practice several years ago to extend the plates 18 in. past the theoretical "cut-off" point but this practice has been changed within recent years. The present A.A.S.H.O. Specification requires the plates to extend at least 12 in. past the theoretical point, while the A.R.E.A. Specification requires the plate to extend far enough to allow two rows of rivets beyond the theoretical point. In planning the tests the committee recommended that the cover plates ex-

tend past the theoretical point a certain amount to agree with one of the current specifications; however, it was pointed out by Prof. Wilson that the plates should be cut-off at the theoretical point so that the stress in the section at the end of the cover plate would be the same as that in the full section under the loading pins. When the tests were planned, the magnitude of the stress raiser produced by the partial length cover plate was unknown, consequently, Prof. Wilson was concerned that if the plates were extended past the theoretical point, the beams would not fail at the end of the plates but would fail at the center instead, and the desired fatigue strength at the ends of the cover plates would not be determined.

In making a thorough study of the test data contained in this report, it is evident that the stress-raising effect of the change in section produced by the partial length cover plate was so large that failure would have occurred at the end of the cover plate even though the plates had been extended past the theoretical point; however, a larger number of cycles would have been required to produce failure. For example, the test data indicates that any beam with partial length cover plates, with end details similar to those shown for specimens 44Bd, subjected to a stress range varying from 0 to 22,100 psi. in the section at the end of the cover plate, will fail after 100,000 cycles. If the cover plates on these specimens had been extended 9 in. past the theoretical point, as suggested by Mr. Ashton, the beams would not have failed until after 300,000 cycles as the stress range at the end of the cover plate under the same load would have been from 0 to 17,700 psi. instead of from 0 to 22,100 psi. It is interesting to note that for beams carrying the same load but subjected to a number of cycles greater than 300,000, the length of the partial, length cover plate would have to be increased over the length recommended by Mr. Ashton.

The development of a partial length cover plate is a complex study but laboratory and theoretical investigations indicate that the development is not instantaneous but occurs over a considerable length of the plate. For this reason it is very doubtful that the 2 in. of weld across the end of the partial length cover plates of specimens 44Bd was stressed to 90,000 psi. as indicated on the diagram of Fig. 1 of the discussion. It is apparent from the tests on the beams with partial length cover plates that the "high concentration of stress on the end welds" of specimens 44Bd was not anymore detrimental than the usual method of attaching the cover plates to the beams as shown for specimens 44Ca and 44Caa. However, some improvement in the fatigue strength can be obtained by using a heavy weld across the ends of the cover plates as shown for specimens 44Ja or by tapering the plate and weld to a feather edge as shown for specimens 44Jc.

Mention is made in the discussion that the bottom cover plates of specimens 44Cd and 44Ce were *accidentally* made long enough. It should be mentioned that the bottom cover plates were made longer so that failure would occur in the top or compressive flange at the end of the top cover plate instead of the tension flange. Failure did occur in these beams at the end of the top or compressive cover plate as shown in the report. The results of these tests indicated that the stress at the ends of the compressive cover plates must be kept about as low as those at the ends of the tension cover plates when the beams are subjected to repeated loads.

Mention is made in the discussion that the riveted specimens were fabricated with less than the minimum safe edge distance to a rolled edge. An edge distance of 1 in. from the center of the rivet to the edge of the beams was maintained for all the specimens tested, which is greater than the minimum distance permitted by the A.R.E.A. Specification. Article 415 of the A.R.E.A. Specification permits an edge distance of $1^1/_4$ times the rivet diameter which would be 0.938 in. for the $^3/_4$-in. rivets used in fabricating these specimens. The A.A.S.H.O. Specification does not have a minimum edge distance for the flanges of beams.

The data presented in the discussion on the stress concentration around holes is well known and can be found in several textbooks on the subject. Possibly the most extensive work on the subject, so far, has been done at Purdue University and this information can be found in AREA Bulletin 495, page 1. Extensive photoelastic studies and SR4 strain gage studies were conducted at Purdue on specimens having variable gage and pitch dimensions. In addition, specimens in single and double shear were also studied.

In the last paragraph of the discussion, Mr. Ashton concludes that our current standard design practices are still sound and our existing structures are still quite safe and in no danger whatever of failing from fatigue, which is in fair agreement with the conclusion stated in the report for flexural members subjected to not over 100,000 cycles of maximum stress range. The validity of these conclusions is substantiated by the record of the large number of beam and girder spans with partial length cover plates which have been in service for a great many years without failure. For example, there are hundreds of such spans in service today on the railroads and very few failures have ever occurred. The short span railroad bridges are subjected to a large number of cycles of stress, in some cases as many as 2,000,000 cycles. However, tests conducted by the A.A.R. research staff have indicated that the maximum stresses are considerably below those calculated and that only about 10% of the trains passing over the bridge produce maximum stresses. In general, it has been found in short span railroad bridges that the magnitude of the actual stresses are well below the fatigue strength as found in the tests conducted by Prof. Wilson.

*Discussion by W. H. Munse**

In view of our laboratory test results, many engineers have wondered why there have not been more flexural fatigue failures in actual structures. Part of the answer can be found in the design procedures, wherein members are proportioned to resist a number of different types of assumed forces such as live and dead load, wind, impact, etc. However, seldom, if ever, will all of the assumed conditions for maximum stress occur simultaneously. For this reason most flexural members will generally be subjected to loads which are somewhat less than those for which they were designed. This appears to be the big stumbling block in any attempt to correlate laboratory studies with field conditions. In the laboratory tests, known loads are applied in each cycle of loading; however, a designer bases his computations on assumed maximum loading conditions and an assumed number of load applications.

Consider, for example, Series 43E and 44E as reported in the paper by Mr. Ruble. These test results are for I-beams with partial length cover plates attached with rivets. Based on the net section, they would require 1,500,000 cycles of stress of 0 to +18,000 psi. to produce failure at the end of the cover plates. In an actual structure the maximum design stress might be 18,000 psi. but it is unlikely that the range of stress will be as large as that used in the tests. In addition, the end fixity of the connections might reduce considerably the maximum stress at the ends of the cover plate. On this basis, it is evident that failures in flexural members of the type considered should not, in general, be expected. Some failures, however, are occurring.

Mr. Ashton, in his discussion of Mr. Ruble's paper, feels that the test results are alarming—they should be. The railroads and highway departments have been finding fatigue failures and cracks in their riveted structures. Since welded structures have been in service a much shorter time than riveted structures, we should not as yet expect failures to be occurring. However, I would not be at all surprised to find fatigue failures in some of our welded bridges after they have been subjected to the same loadings to which the riveted structures have been subjected.

The review presented by Mr. Ashton is an example of what can happen when a design engineer tries to apply laboratory test data to a design without a *careful* analysis of the entire problem. Three of the many important factors which must be considered in fatigue problems are the maximum stress, the range of stress, and the number of applications of these quantities. Failure to consider all of these, as has been done by Mr. Ashton, may be very misleading. The laboratory tests were designed to obtain specific information on the fatigue strengths of various parts of members and at various locations in these members. Although Mr. Ashton would change a few of the details of the specimens, I am sure the same general information would be obtained if his suggested specimens were to be tested.

Consider the Series 44 Bd specimens discussed by Mr. Ashton and shown in his Fig. 1. Mr. Ashton would extend the cover plates to a point 18 in. from the support (5-ft. 6-in. long cover plates). This is exactly the length of the bottom cover plates used for Series 44 Cd, in which case Specimen 44 Cd-1 failed after 716,200 cycles. This failure occurred at the end of the lower (5 ft. 6 in.) cover plate at which point the computed maximum stress was 9860 psi., a value somewhat below that for the 44 Bd specimens which were condemned by Mr. Ashton. The *important* factor to be obtained from these tests is that the fatigue strength for failure at 2,000,000 cycles and a stress cycle of the type used in these tests, is approximately 10,000 psi. at the end of the partial length cover plate. Adding or subtracting a few inches of cover plate is not going to greatly affect the fatigue strength of the beam at the *end* of the cover plate.

On the basis of a fatigue strength of 10,000 psi. for failure at 2,000,000 cycles, it would be necessary to have a welded cover plate at least 6 ft. 7 in. long in order that failure would occur at the center of the beam. Therefore, the beam with the 4-ft. cover plate, as reported in the original paper, had a bending moment capacity for failure at 2,000,000 cycles equal to 51.0 kip ft.; Mr. Ashton's beam would have a capacity of 75.0 kip ft.; a beam with a 6-ft. 7-in. cover plate, or full-length cover plate would have a capacity of 116.3 kip ft., and a 14-in. wide flange section at 42.0 lb. (section modulus = 60.7, very nearly the same as the beam with cover plate) would have a resisting moment equal to approximately 157.5 kip ft. This comparison shows the effect of the welded cover plate and its length upon the bending moment capacity of the member.

Another series of tests questioned by Mr. Ashton is Series 44 Ga. This series was questioned because the $^1/_8$-in. weld which was used was only 73% of what Mr. Ashton would recommend. However, if Mr. Ashton will check Series 44 Gb, he will see that the beams fabricated with $^5/_{16}$-in. weld had a slightly lower fatigue strength than did those fabricated with the $^1/_8$-in. weld. I might also point out that although the weld area was not as large as Mr. Ashton would have liked, the welds did not fail; the failures occurred in the bottom flange of the beams.

I would agree wholeheartedly with Mr. Ashton in that, "All engineers should pay more attention to details in their design." However, I am not as sure as Mr. Ashton that our structures are safe from fatigue failures and that there is no danger. Fatigue is an old-age disease, and it is not until the structures are old that failures occur. This is the situation at present for our older riveted structures and accounts for many of the failures which have been found during the past few years.

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Discussion by Frederick H. Dill

This report of Fatigue Tests of Beams in Flexure makes some very excellent contributions to the general principles that govern the design of structures to resist repeated applications of load. It rather effectively disproves the common notion that there is benefit from tapering the width of cover plates at their terminations and it emphasizes the fact that partial length cover plates reduce the fatigue strength of flexural members.

The data in the report give general levels of fatigue strength, but there is some question of how accurate any specific extrapolation of the data to bridge-size members would be. When fillet weld size is brought down as small as it was in some of these tests the magnitudes of roughnesses and internal defects, such as gas holes and occasional lack of fusion, do not reduce in proportion to weld size. They become large in proportion to the cross section of the weld and the cross section of the member. There is a possibility, therefore, that some of the details studied, such as the beams with continuously welded full length cover plates, might have greater strength when made with larger material and larger welds.

Conversely, there are some details which would in extrapolation have exorbitantly large welds. For example, the $^{9}/_{16}$-in. fillet welds used for attaching $^{9}/_{16}$-in. thick cover plates would become $1^{11}/_{16}$-in. fillet welds in extrapolation to a 36-in. beam. Even the $^{3}/_{16}$-in. welds would become $^{9}/_{16}$-in. fillet welds and thus are representative of less abrupt transition than may be expected on full size members where $^{5}/_{16}$- and $^{7}/_{8}$-in. fillet welds are commonly used. There is a possibility here that some of the tests of cover plate terminations may show greater strength than can be had in bridge-size pieces.

The tests of butt-welded splices of beams show results that are much lower than would be expected from the data developed in other tests of butt welds. Examination of *University of Illinois Bull. 332*, which provides more detail of the tests than the report under discussion, shows that some of the specimens for the B and C series of tests had flaws in them that would not be acceptable even in commercial welding. The class of electrodes used, E6012, is a class generally considered unsuitable for butt welding steel over $^{3}/_{8}$ in. thick and the welding was done with currents much too low for the sizes of electrodes used. There was also a splitting of weld passes that is a questionable technique on any size of beam and completely unjustified on beams as small as those used in this test. It is no wonder that some of the specimens failed after a very few applications of load. It is rather shocking to find the results of tests of such welds published as representing the value of butt-welded splices in rolled beam sections.

"Make some more tests" is an almost too frequent answer to questions about engineering problems, but here there does seem to be need for more information. Perhaps the questions of the relative importance of weld size can be answered from analysis of data on hand, but there certainly should be a re-examination of the fatigue strength of butt-welded splices of rolled beam sections before the findings of this investigation and its report are accepted.

Frederick H. Dill is Welding Engineer, American Bridge Co.

Author's Reply

The criticism offered by Mr. Dill regarding the size of the specimens tested and the extrapolation of the data to larger size members can equally be applied to any of the fatigue tests so far conducted in this country. In general, the committee planning the tests did not consider them to be model but rather tests of actual structures. There are many of the older highway and railroad bridges in service today where 12- and 15-in. sections have been used as stringers or beam spans. Within recent years many of these beams have been "reinforced" by welding on cover plates, with cover plate thickness and weld size very similar to those tested. Surely these laboratory tests will apply to these structures.

As an indication that the results of these tests may be applied to larger sections, Prof. Munse of the University of Illinois reported that a fatigue failure had occurred in the "walking beam" of one of their fatigue machines. This beam consists of a 24-in. I-beam reinforced with welded side plates and cover plates and failure occurred on a section where the maximum stress cycle was equivalent to a stress varying from zero to 9000 psi. in tension. This stress is approximately the same value as that obtained for the beams with partial length cover plates.

The fatigue strength of the welded spliced beams was determined as about 16.0 ksi. at 2,000,000 cycles of stress which does not appear to be so far out of line considering that the splice was subjected to both bending and shear. In comparing the fatigue strength of the welded spliced beams with the fatigue strength of commercial butt welds in structural steel plates, *Univ. Ill. Bull. 344*, it can be seen that the strengths are comparable. Fatigue strengths in direct tension as low as 16.5 ksi., with a general average of 22.5 ksi., were obtained for the butt-welded specimens purchased from fabricating shops that have had extensive experience in structural welding, so it is doubtful if higher fatigue strengths can be expected on welded spliced beams subjected to both bending and shear.

The fabrication of the welded specimens was done entirely in the University of Illinois laboratory by an experienced welder. Professor Munse states that the welder had obtained his experience in several large fabricating and ship-building concerns. In the preparation of the test specimens, the welder was instructed to weld the specimens with the procedure he considered most suitable. The procedure followed was similar to that being used at Columbia University for the impact studies of butt-welded beams.

The flaws in the specimens are undoubtedly typical

of what would be found in industry. In general, the flaws appearing in the fractured butt-welded beams appear to be about the same as those found in the fractured commercial butt-welded tension specimens as reported in *University of Illinois Bull. 344*.

It was suggested by Mr. Dill that additional tests be conducted to secure more information on the subject. However, it should be pointed out that the specimens tested were about the maximum that could be used in the fatigue machine so that additional tests would not overcome his criticism of specimen size. The criticism regarding the technique employed in fabricating the butt-welded beams could possibly be answered by testing a larger number of commercially fabricated specimens but in view of the results obtained on the commercial butt-welded specimens in direct tension, it is doubtful that the average fatigue strength would be increased very much.

Properties of Metals Used at Low Temperatures

THE annual Metallurgical Conference and open house held at the National Bureau of Standards on May 14 and 15, 1951, was comprised of a three-session symposium on the "Influence of Low Temperatures on the Mechanical Properties of Metals" with a predominance of papers from outside the Government services. Nine papers and one narrated movies, including both theoretical and applied considerations, were presented. This symposium, attended by more than 250 metallurgists and engineers representing many parts of the nation, was one of a series on scientific subjects being sponsored by the Bureau in connection with its semicentennial celebration (1901–51). Through the cooperation of the Office of Naval Research it was possible to include a foreign speaker on this program.

The opening paper, by R. L. Smith, G. A. Moore and R. M. Brick, of the University of Pennsylvania, a summary of a study of the influence of low temperature on the tensile properties of high-purity iron-carbon alloys containing 0.05 to 0.5% carbon, treated to obtain A.S.T.M. No. 5 grain size with medium pearlite, showed that yield point values increase along S-shaped curves with decreases in temperature to −192°C. (−314°F.). Graphs were presented showing that fracture stress for the alloys increased nearly linearly with decreasing temperature to about −150°C. (−238°F.) and then fell off rapidly as the temperatures were decreased further, indicating that the transition for all of these alloys occurred at about −150°C. Total strain decreased slowly with decreasing temperature until the transition was reached and thereafter occurred more rapidly. Flow-stress values at constant strains increased at increasing rates with decreasing temperatures. Increases in carbon content caused nearly linear increases in yield point, slight increases in fracture stress, decreases in total strain and increases in flow stress at a constant strain and temperature.

Morgan Williams, of the Bureau of Standards, who discussed "Brittle Fractures in Ship Plates," indicated that weld failures in merchant ships, usually occurring at low temperatures and generally traceable to notch effects resulting from faulty design or welding, had cost this country about $50,000,000 during the last decade. Although the report showed that failures had been reduced considerably by improvement of design details and welding workmanship, it was stressed that these factors alone cannot entirely eliminate the failures, since many are traceable to the quality of steel, especially with respect to their notch sensitivity. Statistical interpretation of Charpy V-notch test data indicated that under the conditions existing in the structure of a ship, the probability of initiation of fracture in a plate increases markedly with increasing notch sensitivity of the steel, as measured by the 15 ft.-lb. transition temperature. Correlation of these Charpy data with chemical compositions of the steels investigated showed that notch sensitivity increased with increased carbon, phosphorus, molybdenum and arsenic contents, and decreased with finer grain size and increasing amounts of silicon, manganese, copper and nickel. However, the combined effects of these elements are not simply additive.

A reasonably dependable basis for evaluating the maximum transition temperature based on the chemical composition and grain size of the steels studied was obtained by the formula:

(Max.) 15 ft.-lb. transition temperature, °F. =
$100 + 300 \times \%\,C + 1000 \times \%\,P - 100 \times \%\,Mn - 300 \times \%\,Si - 5 \times$ A S.T.M. ferritic grain size number

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Although the thicker plates had higher transition temperatures, it was attributed to the fact that they had correspondingly coarser grains than the thinner plates.

STEELS FOR LOW-TEMPERATURE SERVICE

J. B. Austin, of the Research Laboratories, U. S. Steel Co., discussing "The Manufacture of Steels for Low-Temperature Service," pointed out that, while the notch toughness as indicated by the notched-bar impact test is one of the most satisfactory and widely used of the criteria for ascertaining the suitability of metals for low-temperature service, the type of specimen, design of notch and rate of straining must be considered in establishing a statistical index of low-temperature performance based on such tests.

The microstructure of ferrous metals in a general manner influences the transition temperature at which the material undergoes a change from tough to brittle behavior; the lowest transition temperature is obtained when the structure is austenitic. In ferritic steels, the heat treatment capable of producing the lowest transition temperature for a given hardness appears to be full martensitic hardening and subsequent tempering to the desired hardness level. A completely pearlitic structure obtained by continuous cooling at a rate to attain the desired hardness tends to give the highest transition temperature although it is lowered as the mean distance between the lamellae decreases. Intermediate transition temperatures are obtained with mixed structures of pearlite and tempered martensite. An addition of about 9% nickel yields a steel with a very low transition temperature, even as normalized and tempered. Dr. Austin's comments regarding the influence of grain size, carbon, phosphorus and manganese contents were substantially in accord with those stated by Dr. Williams.

It was pointed out that in controlling grain size, finishing temperature is very significant, the tendency being for decreasing transition temperatures in the steels finished at the lowest temperatures. For a silicon-killed steel containing 0.23% carbon and 0.45% manganese, transition was lowered about -6.7°C. (20°F.) for each unit decrease in A.S.T.M. grain size number. (It is about -1.1°C. (30°F.) in semikilled steel.) In general, the transition temperature is lower the better the deoxidation of the steel, although other factors, such as heat treatment, may alter the results. Data indicated that heats deoxidized with aluminum and silicon produced the lowest transition temperature, the maximum benefit obtained with high manganese content.

Quoting the results of Rinebolt and Harris, who investigated the effects on the transition of different elements in a base steel containing 0.30% carbon, 1.00% manganese and 0.30% silicon and having the same coarse pearlitic structure and grain size (A.S.T.M. 7 to 8), it was stated that small increases in carbon, molybdenum and phosphorus significantly raised the transition temperature. Silicon and copper had somewhat less effect, while chromium and boron appeared to cause no change. Additions of nickel in amounts up to 3% caused measurable lowering of the transition temperature and manganese produced a more marked effect in the same direction, being particularly effective when the ratio of manganese to carbon is high. An increase also was caused by titanium and vanadium in amounts of less than 0.2%, but additions above this caused decreases. Addition of an alloying element may change not only the transition temperature but also the shape of the energy-temperature curve. Dr. Austin observed that he was in full agreement with Dr. Williams, in that the effects of the elements noted were not simply additive when present as combinations in steel, since certain significant interactions of elements may occur.

ELASTIC PROPERTIES OF METALS

N. P. Allen, of the National Physical Laboratory, Teddington, England, who attended the meeting as the foreign guest and representative, presented some theoretical considerations of low-temperature effects on metals, based on recent studies by the National Physical Laboratories and other investigators in England and Continental Europe. He pointed out that while most of the experimental work has attempted to determine the behavior of the common engineering metals and alloys as the temperature is lowered, there is at present a revival of interest in the elastic properties of metals, since they provide the most direct approach to the study of the mechanism associated with the behavior of metals and alloys at low temperatures.

Results of other studies reveal that changes in the crystallographic mechanism of slip with lowering in the testing temperature causes a change in the *mode* of slip. With aluminum, the first stage of deformation is much the same at all temperatures and it consists of the formation of widely spaced zones of simple slip. Further deformation at low temperatures produces more zones of simple slip at closer spacings until a minimum is reached, after which additional slip lamellae may appear in each zone. At high temperatures, the minimum spacing is wider and further deformation produces new slip lamellae in each zone. The greater strain hardening at low temperatures is attributed to more numerous slip zones occurring at the low temperatures.

Investigations correlating the proof stress ratios to the type of lattice and to the temperature were also reviewed. Studies with high-purity iron at the National Physical Laboratory indicated that the V-notch bar impact transition temperature is very sharp and occurs at about -15°C. (5°F.). Additions of carbon within the range of 0.01 to 0.03% sharply raise the transition temperature, thus indicating that carbon in iron exerts an embrittling effect.

However, additions of manganese to the pure iron and the iron containing a little carbon lower the transition

temperature, which suggests that manganese has a profound effect on the condition of the carbon in the iron—and this, he considers, is at least as important as the effect of the dissolved manganese atoms. Oxygen in excess of 0.003% causes a marked increase in the transition temperature, and the appearance of intercrystalline fracture in such materials indicates a weakening of the cohesion at the boundaries. Such embrittlement may be closely associated with intercrystalline films. It is quite conceivable that this filming has an important bearing on the lowering of the transition temperature by the expedient of grain refinement.

Mr. Allen stated that such grain boundary films could be less concentrated and of smaller dimensions in the finer grain materials, thereby lessening their effect on the cohesive strength between the grains. Iron containing oxygen thus provides a clear example of a material containing a serious weakness, which is not detected by a tensile test at room temperature and is detected by a notch-bar test or a test at low temperature. With respect to alloying additions, it appears that the elements of small solubility generally appear to be the most effective in producing brittle fractures, thereby raising the transition temperatures. The solution effect of heat treatment generally results in a transition temperature which is lower than that obtainable in the untreated material.

D. A. Shinn, of Wright-Patterson Air Force Base, presented a paper prepared in collaboration with J. B. Johnson, also of Wright-Patterson, on "Application of Metals in Aircraft at Low Temperatures." He stated that the lowest temperature which modern aircraft will encounter in stratosphere flight is about –90° C. (–130°F.). However, shock loading at low altitudes is not critical, unless the member is subjected to ballistic or explosive impacts. The laboratory data on standard and notched specimens at low temperatures indicate that the allowable design values determined at room temperatures for standard aircraft metals are safe for low-temperature operations. Most low-temperature failures of aircraft materials are caused by unequal contraction of dissimilar materials which produces galling or binding with resultant overstress and distortion failures. Because of the scarcity of alloying elements, the use of valuable alloy to reduce the transition temperature should await a thorough diagnosis of the effect of lowered ductility at subzero temperatures on the serviceability of the part.

V. N. Krivobok, of International Nickel Co., Inc., in his paper, "The Properties of Austenitic Stainless Steel of Low Temperatures," presented data showing the effect of composition, heat treatment and cold working. The beneficial influence of extra-low-carbon content in the austenitic stainless steels is particularly note worthy Data on modulus of elasticity, fatigue, impact, tensile impact and other properties were summarized and appraised. Although the hardened high-chromium stainless steel has higher strength characteristics than the 18–8 type at room temperature, the low-temperature properties of the latter are considerably better, particularly as regards toughness. It is noteworthy that the ultimate tensile strength of 18–8 is greater for the notched specimen than for the unnotched type. Data were presented showing that while the impact values at room temperature for 18–8 are lower in the notched than in the unnotched bars, the ductility in the notched bars was at least as high. At subzero temperatures, the notched specimens showed the greater impact and ductility values.

Walter Crafts and C. M. Offenhauer, from Union Carbide and Carbon Research Laboratories, presented data on low-temperature service of a special low-alloy chromium-copper-nickel steel containing carbon 0.12% max., manganese 0.65 to 0.85%, silicon 0.15 to 0.25%, copper. 040 to 0.60%, nickel 0.50 to 0.75% and chromium 0.65 to 0.85%. Such steel has rather good atmospheric corrosion resistance, welds readily and has successfully served for over 15 years in several installations at temperatures as low as −80° C. (−112° F.). Recent tests have indicated that certain heats of these steels retain good toughness at −100° C. (−148° F.). These studies indicated that the limiting factor was the appearance of the "pseudo-martensitic" microstructural constituent, controlled mainly by the amount and balance of carbide-forming elements and secondarily by the austenite-forming elements. Aluminum tended to inhibit the formation of this nonpearlitic constituent and also was a significant factor in lowering the transition temperature. It was concluded that consistent notch-bar impact strength can be realized in the alloy at −100° C. if the residual aluminum is high enough to insure persistently fine grain size, and further lowering of the transition was indicated if the residual aluminum content approached the 0.2% level.

SIZE AND DESIGN FACTORS IN FRACTURE

C. W. MacGregor and N. Grossman, of Massachusetts Institute of Technology, presented a paper which dealt primarily with dimensional and design effects of test specimens on their fracture characteristics. Flat circular disks of 0.95% carbon steel, simply supported around the circumference and loaded by a concentrated force at the center, were tested at constant deflection rates and at various constant temperatures. Comparisons were made of the transition temperatures for brittle fracture at the same effective strain rates rather than at equal deflection rates in order to maintain dynamic similarity. Size effect in the ratio ranges of 6 to 1 for the material tested had no significant effect on the brittle transition temperature. Rectangular plates 1/8 in. thick of the same steel, simply supported on two sides only, were centrally loaded to study the influence of biaxiality of stresses on the brittle transition temperatures. Ratios of the supported lengths to the unsupported lengths varied from 0.5 to 2.667, which produced a variation of the biaxiality of stresses from 0.483 to 0.855. Together with the circular disks previously described, these limits would be 0.483 to 1.0. The brittle transition temperature, the fracture stress, and con-

straint effect were found to increase with increase in the biaxiality ratio.

The closing paper, "Tensile Properties of Copper Nickel and Some Copper-Nickel Alloys at Low Temperatures," by G. W. Geil and N. L. Carwile, of the National Bureau of Standards, discussed tension data obtained at temperatures ranging from +100 to −196° C. for high-purity copper and nickel and for the 70–30 and 30–70 alloys of these metals in the annealed conditions. The "rim effect" (contraction of the specimens at the base of the neck during actual fracture) was considerable and tended to decrease as the temperatures were lowered. Because of this rim effect, accurate values of the true stress (σ) and strain (δ) at fracture can be determined only from measurements made at the initiation of fracture. The true stress-strain tension data did not conform to the commonly accepted parabolic relationship $\sigma = k\delta^m$, but the strength indexes, as represented by the initial strength, nominal ultimate stress, true stress at maximum load and true stress at initial fracture, increased continuously with decrease in temperature within the range tested. The uniform strain (true strain at maximum load) generally increased with decrease in test temperature; however, no general trend was indicated in the slight variation of total strain (true strain at initial fracture) with temperature. The rates of work hardening at specific true strain, in general, increased continuously with decreased temperatures. For small true strains, the increase in the rates of work hardening of the cupro-nickel and the 70% nickel, 30% copper alloy with decrease in temperature was less than that of either the copper or nickel, but for larger true strains (greater than 0.2), the work-hardening rates were greater for the alloys.

An interesting moving picture, narrated by M. J. Disckind, of Towne Scientific School, University of Pennsylvania, recorded the progress of the transformation of white (β) tin to the gray (α) form at −20°C. (−4°F.). Cast polycrystal and single crystal specimens of high-purity tin were the actors. To facilitate the transformation, a seed of gray tin was impressed in the surface of each specimen before it was cooled. In the polycrystal specimens, the transformation progressed as a solid geometric figure outward toward the edges of the specimen. The process was completed in about 12 hr. and was accompanied by an increase in volume and disintegration of the metal. In the single crystal (which first was cold worked before "seeding") the transformation proceeded at first as a series of dendritic-like darts and then the transformation continued from the center of the specimen, much like that in the polycrystal material.

According to present plans, the series of nine papers will be published as a single volume at some future date.

WELDING RESEARCH COUNCIL BULLETINS

The Welding Research Council has inaugurated a series of Bulletins to include reports for which space cannot be provided in the regular Welding Research Supplement. These Bulletins are furnished to the contributors and research workers of the Council and placed on sale at a nominal charge through the AMERICAN WELDING SOCIETY. A list of the Bulletins published to date and their prices are:

No. 1. *Steel Compositions and Specifications*, by Charles M. Parker, March 1949. Price: Fifty cents.

No. 2. *The Nature of the Arc*, by J. D. Cobine, April 1949. Price: Fifty cents.

No. 3. *Burn-Off Characteristics of Steel Welding Electrodes*, by D. C. Martin, P. J. Rieppel and C. B. Voldrich, May 1949. Price: Fifty cents.

No. 4. *Testing Pressure Vessels*, by F. G. Tatnall, and *Effect of Welding on Pressure Vessel Steels*, by A. F. Scotchbrook, L. Eriv, R. D. Stout and B. G. Johnston, February 1950. Price: Fifty cents.

No. 5. *How Plastic Deformation Influences Design and Forming of Metal Parts*, by John R. Low, Jr., and *Brittle Fracture in Mild Steel*, by J. S. Hoggart, May 1950. Price: One dollar.

No. 6. *Stress Corrosion Cracking of Stainless Steels*, by Helmer Nathorst. Part I—Practical Experiences; Part II—An Investigation of the Suitability of the U-bend Specimen, October 1950. Price: One dollar.

No. 7. *Instrumentation for the Evaluation of the Stability of the Welding Arc*, by L. P. Winsor, L. McDonald Schetky and R. A. Wyant, November 1950. Price: One dollar.

No. 8. *Tests of Columns Under Combined Thrust and Moment*, by L. S. Beedle, J. A. Ready and B. G. Johnston, December 1950. Price: One dollar.

No. 9. *Copper in Stainless Steels*, by Helmut Thielsch, August 1951. Price: One dollar.

Further Tests on Effects of Plastic Strain and Heat Treatment

Effect on transition temperature of pressure-vessel steels of 20% tensile strain, cylindrical treating and hot- or cold-spherical pressing

by Sadun S. Tör, Robert D. Stout and B. G. Johnston

FOREWORD

THIS report is the sixth in a series describing results of the research conducted at Lehigh University for the Pressure Vessel Research Committee of the Welding Research Council. The aim of the research project is to determine the effects of fabrication operations such as welding, forming and heat treating on the mechanical and physical properties of pressure vessel steels.

In the earlier reports were described methods of transition temperature determination,[1] metallurgical and physical variations between heats and within heats of two pedigreed steels,[2] the effect of plastic strain up to 10% combined with various heat treatments,[3] the effects of welding,[4] the relation between transition temperatures and tensile test results.[5]

This report covers transition-temperature-test results of two pressure-vessel steels in the following conditions. (1) as-received, (2) after 20% permanent tensile strain, (3) after cylindrical bending and (4) after hot- or cold-spherical pressing.

TESTING PROCEDURE

Testing for this project to determine transition temperatures was carried out according to the following program.

1. 5/8-in. material as-received, followed by heat treatment at room temperature, at 500° F., at 1150° F. or at 1600° F.
2. 5/8-in. material 20% tensile-strained followed by heat treatment at room temperature, at 500° F., at 1150° F or at 1600° F.
3. 1 1/4-in. material cylindrically bent to give 5% tensile strain at the locus of the V-notch.
4. 5/8-in. material spherically pressed hot and cold.

STEELS

The steels used in the investigation were 5/8-in. and 1 1/4-in. thick plain carbon steel from two different heats. One of the steels was aluminum-killed A.S.T.M. A-201 steel, the other was rimmed A.S.T.M. A-70 (now A.S.T.M. A-285) steel. These are "pedigreed" steels and complete heat records were given in an earlier report.[2]

In the present phase of the work material 1 1/4-in. thick was used only in the 5% cylindrically bent test specimens. This was done to afford a basis of comparison of 5% cylindrically strained material results with those of the 5% tensile-strained 1 1/4-in. material reported in Progress Report 3. A complete chemical analysis of the steels used is given below.

Chemical Composition of Materials

	A-201	*A-70*
Carbon	0.15	0.20
Manganese	0.53	0.35
Sulphur	0.025	0.028
Phosphorus	0.020	0.018
Silicon	0.19	0.02
Nickel	0.05	0.10
Chromium	0.04	0.05
Copper	0.08	0.14
Tungsten	0.04	0.05
Vanadium	0.02	0.02
Molybdenum	0.01	0.01
Aluminum	0.026	0.021
Alumina	0.002	0.003
Nitrogen	0.003	0.003

SPECIMEN PREPARATION

Slow-Notch-Bend Specimens of As-Received and As 20% Tensile-Strained Material

The specimen used for determining the transition

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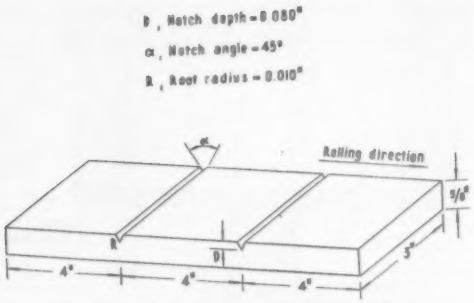

Fig. 1 Lehigh slow-notched-bend specimen

temperature of plates in the as-received and as 20% cold-strained condition is represented in Fig. 1. In the case of the strained specimens the straining was done prior to heat treatment and machining. Six-foot strips of the steels 3.3 in. wide were scribed at 6-in. intervals, and stretched in a Baldwin-Southwark 300,000-lb. machine until the desired 20% strain was obtained. Occasionally certain portions of the strip had to be reinforced by clamping lengths of steel bars to prevent local necking. The final strain obtained was 20% $\pm 1^1/_2$%. From each end, one foot of material was discarded and the middle section was then cut into four 12-in. lengths. The specimens to be tested after room temperature aging were notched immediately. The other specimens were heat treated

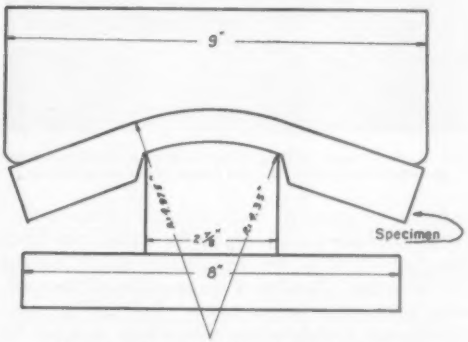

Fig. 2 (a) Cylindrical-bend jig and specimen

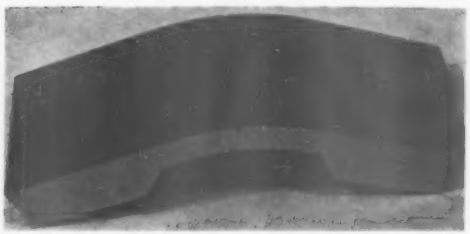

Fig. 2 (b) Cylindrically bent specimen

first and then notched. Transition-temperature tests were run 7 days after the heat-treatment operation. Twelve double-notched specimens or 24 slow-notch-bend tests were run to determine the transition temperature. Two series of tests were made; the first series was strained parallel to the rolling direction and the second series was strained transverse to the rolling direction. Testing was done in the direction of straining.

Slow-Notch-Bend Specimens of 5% Cylindrically Bent Material

The materials used for 5% cylindrically bent specimens were A-70 and A-201 steels in the $1^1/_4$ in. thickness. The specimens for this investigation were 9 in. long, 3 in. wide and $1^1/_4$ in. thick, with the middle 3 in. machined on one side to a final thickness of $^5/_8$ in., Figs. 2 (*a*) and 2 (*b*). A special bending jig, which would bend the specimen cylindrically to give a permanent tensile strain of 5% at a distance of 0.08 in. from the unmachined side was designed and built. After bending, the specimens were heat treated at room temperature, at 500° F., at 1150° F. or at 1600° F. They were then notched and tested seven days after heat treatment.

Spherical Test Specimens

The conditions for this test were such that the slow-notch-bend specimen of Fig. 1 could not be readily adapted to them; therefore, it was necessary to develop a completely new specimen to study the effect of spherical forming on these steels.

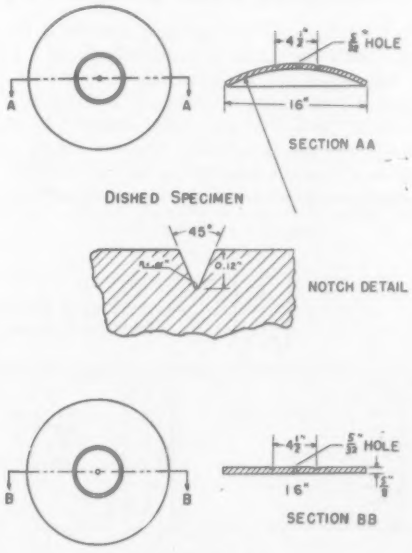

Fig. 3 Flat specimen

The specimens used in this test were 16-in. diameter circular plates made from $^5/_8$-in. A-70 and A-201 steels, Fig. 3. They were tested in the as-received, as-hot-pressed and as-cold-pressed conditions. The specimens had a 0.12-in. deep circular V-notch, machined at a radius of $2^1/_4$ in. The specimens were first pressed and then notched on the convex side. No postheat treatment was used. A pilot series of 6 specimens was cold pressed to a spherical radius of 16 in. at Lukens Steel Co., Coatsville, Pa. The series used for the main testing program was pressed at the Commercial Shearing and Stamping Co., Youngstown, Ohio. The cold forming was done in one operation in an 800-ton mechanical press.

The hot forming was done in the same press, but prior to being formed the specimens were heated in an oil furnace at a temperature of between 1550 and 1650° F. An optical pyrometer was used to determine the furnace temperature. The specimens were still red hot when they were removed from the press; they were cooled in air.

TRANSITION TEMPERATURE TESTS

Tests on Straight and Cylindrically Bent Specimens

Transition temperature tests on the straight and cylindrically bent specimens were performed on the standard, Lehigh slow-notch-bend testing jig, Fig. 4. The technique of testing followed in these tests has been reported in detail in earlier reports.[1, 3]

Tests on Spherically Pressed Specimens

The testing jig used for these tests is shown in Figs. 5 and 6. Since the results of spherically pressed specimen tests could not be compared directly with the straight slow-notch-bend specimens, a series of tests was run on both A-70 and A-201 steels $^5/_8$-in. thick in the unpressed condition. The specimens were placed in a constant-temperature bath of gasoline and dry ice for tests below room temperature, and a hot water bath was used for tests above room temperature. When the desired temperature was attained the specimens were kept at this temperature for 15 minutes before testing. Because of the geometry of the specimen, contraction measurements could not be made. Autographic load-deflection curves were obtained for each specimen and from these total energy-to-fracture values were obtained. This energy is the criterion used in plotting the transition-temperature curves. The circular notch was visible to the observer throughout the test.

The same procedure was used in testing the pressed specimens.

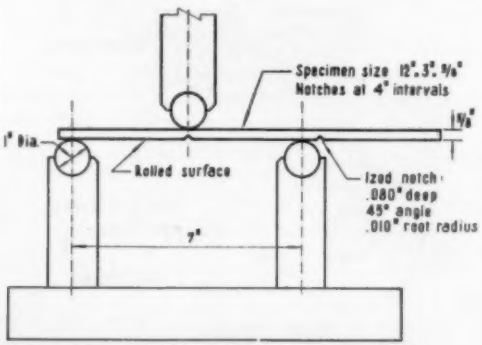

Fig. 4 The Lehigh slow-notched-bend test

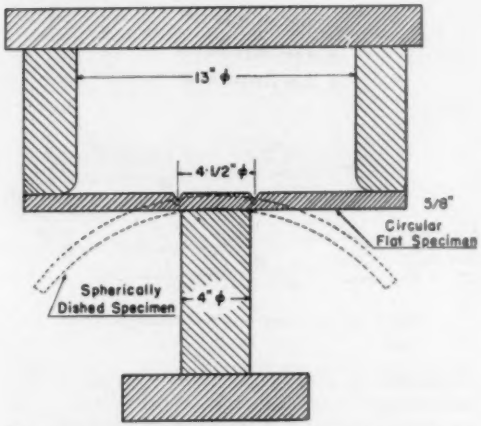

Fig. 5 Cross section of bending jig showing the relative positions of piston, specimen and support

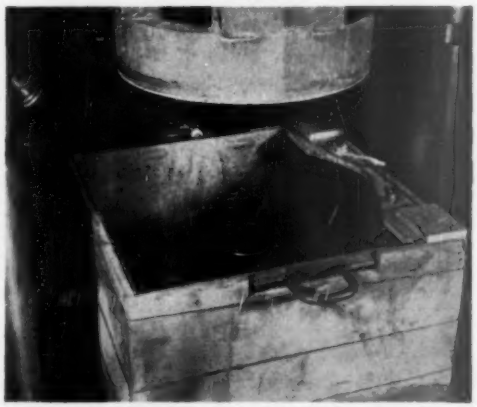

Fig. 6 Spherical testing setup showing constant-temperature bath with the specimen ready to be tested

DISCUSSION OF THE RESULTS: TRANSITION CURVES

As-Received Material

The transition curves for A-201 and A-70 steels in

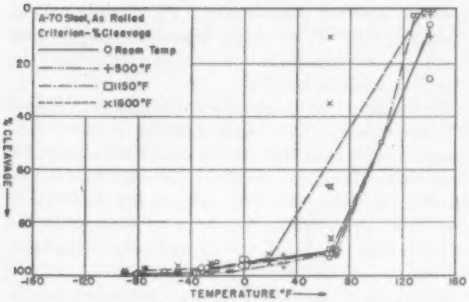

Fig. 7 Transition temperatures showing the effects of heat treatment on ⁵/₈-in. A-70 steel, as-rolled

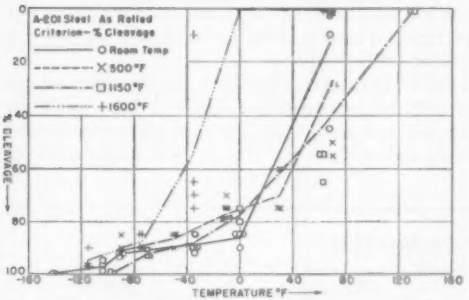

Fig. 8 Transition temperatures showing the effects of heat treatment on ⁵/₈-in. A-201 steel, as-rolled

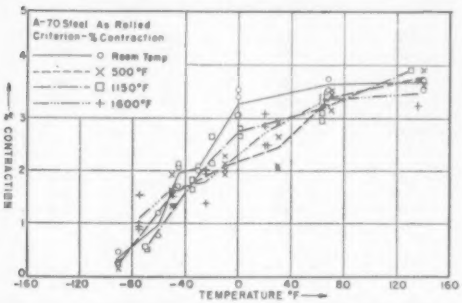

Fig. 9 Transition temperatures showing the effects of heat treatment on ⁵/₈-in. A-70 steel, as-rolled

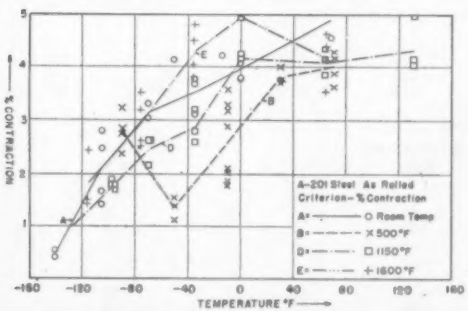

Fig. 10 Transition temperatures showing the effects of heat treatment on ⁵/₈-in. A-201 steel, as-rolled

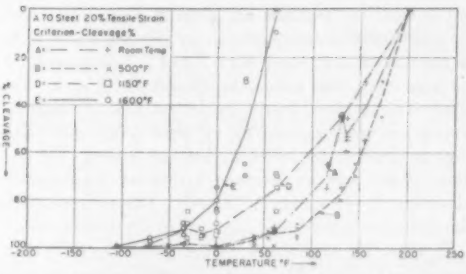

Fig. 11 Transition temperatures showing the effects of heat treatment on 20% tension A-70 steel, parallel to rolling direction

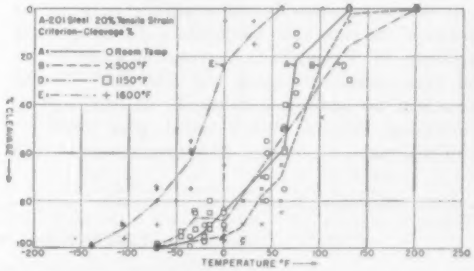

Fig. 12 Transition temperatures showing the effects of heat treatment on ⁵/₈-in. A-201 steel, 20% tensile strain parallel to rolling direction

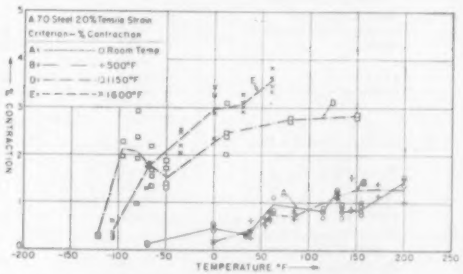

Fig. 13 Transition temperatures showing the effects of heat treatment on ⁵/₈-in. A-70 steel, 20% tensile strain parallel to rolling direction

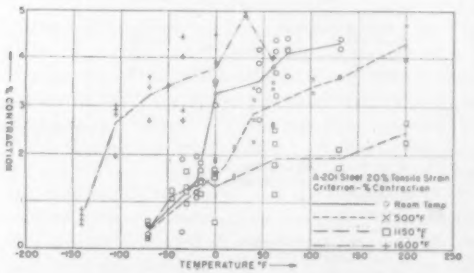

Fig. 14 Transition temperatures showing the effects of heat treatment on ⁵/₈-in. A-201 steel, 20% tension parallel to rolling direction

the as-received condition are given in Figs. 7, 8, 9 and 10, and transition temperatures are given in Table 1, A. In the case of A-70 steel, Figs. 7 and 9, it is interesting to note that the transition temperatures were not affected to any great extent by the postheat treatments. Transition temperature, T_B, of steel A-201 only was slightly affected by 1600° F. heat treatment (Fig. 8). Steel A-201 has an average transition temperature about 60° F. lower than A-70 steel. This substantiates the data established and reported in the earlier tests.[3]

In Figs. 11, 12, 13 and 14 are given the transition curves for $^5/_8$-in. A-201 and A-70 steels strained parallel to the rolling direction. In Figs. 15, 16, 17 and 18 are given the transition curves of the same steels strained transverse to the rolling direction.

In the case of material strained parallel to the rolling direction the transition temperature T_N is increased by about 80° F. and T_B is increased by about 30° F. for room-temperature aging and after 500° F. heat treatment an additional 10–30° F. as compared to unstrained material. When tested after 1150° F. heat treatment, the T_N transition temperature of both steels is lowered considerably, T_B slightly. Heat treating at 1600° F. lowers the transition temperatures T_N and T_B of both steels down to, or even below, the level of unstrained material.

The transition-temperature level for material strained 20% transverse to the rolling direction is raised considerably more than that for material strained parallel to the rolling direction. It should be noted that straining 20% in either direction reduces the ductility of these steels as shown by the per cent contraction T_N values in Figs. 13, 14, 17 and 18, and only normalizing restores the original ductility level.

In Figs. 19, 20 and 21 the data are presented graphically to illustrate the effects of heat treatment more clearly. The lines connecting the points do not indicate the trend between the heat-treatment levels but are intended merely to tie one point with the other to facilitate their study.

Figure 19 compares the T_N transition temperatures at different heat-treatment levels of both steels as-received and after 5 and 20% tensile strain parallel to the rolling direction. Figure 20 is a comparison of

Table 1—Lehigh Slow-Notch-Bend Tests

	Transition temperature, ° F.					
	T_N		T_E		T_B	
	A-201	*A-70*	*A-201*	*A-70*	*A-201*	*A-70*
	$^5/_8$-in. material, as-received					
A. Tested parallel to rolling direction						
Heat treatment						
Room temperature	−93	−46	−103	−48	34	103
500° F.	−29	−26	−23	−36	49	103
	−68	..	−75	..	..	..
1150° F.	−82	−28	−78	−33	51	94
1600° F.	−92	−39	−91	−32	−32	64
	$^5/_8$-in. material, 20% strained					
B. Strained parallel to rolling direction						
As-strained	−12	43	−27	27	66	140
500° F.	21	71	−8	53	78	161
1150° F.	−34	−56	−57	−49	69	118
1600° F.	−108	−65	−112	−60	−24	30
Strained transverse to rolling direction						
As-strained	58	39	..	..	82	147
500° F.	132	133	..	..	137	173
1150° F.	25	76	..	..	76	..
1600° F.	−90	−36	−100	−39	−67	29
	$1^1/_4$-in. material					
	Machined down to $^5/_8$-in. strianed, 5% cylindrical					
C. Strained parallel to rolling direction						
As-strained	−73	−42	−83	−22	−90	163
500° F.	−52	−9	−27	17	101	148
1150° F.	−43	−15	−60	−33	88	149

Spherical Tests

	$^5/_8$-in. Material, circular specimens	
	A-201	*A-70*
D. Transition temperature, T_E (at 50% of maximum energy)		
As-received	−18	10
Hot pressed	−20	−3
Cold pressed	−5	13
E. Transition temperature, T_E (at 10,000 ft.-lb. level)		
As-received	−16	45
Hot pressed	−23	−8
Cold pressed	30	82

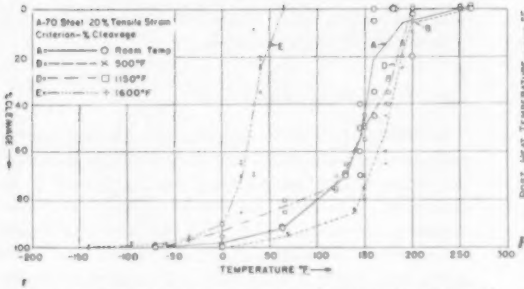

Fig. 15 Transition temperatures showing the effects of heat treatment on $^5/_8$-in. A-70 steel, 20% tensile strain perpendicular to rolling direction

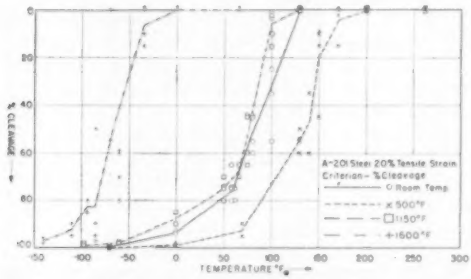

Fig. 16 Transition temperatures showing the effects of heat treatment on $^5/_8$-in. A-201 steel, 20% tension perpendicular to rolling direction

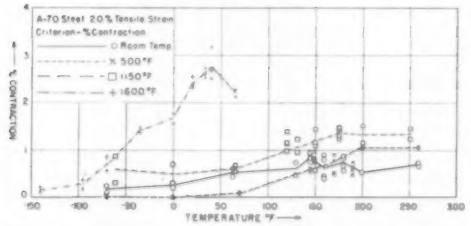

Fig. 17 Transition temperatures showing the effects of heat treatment on $^5/_8$-in. A-70 steel, 20% tension perpendicular to rolling direction

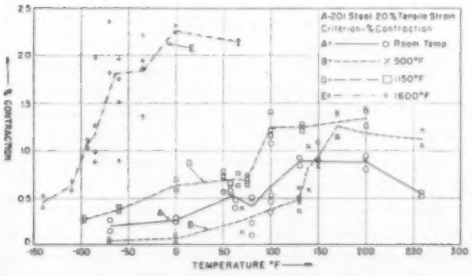

Fig. 18 Transition temperatures showing the effects of heat treatment on $^5/_8$-in. A-201 steel, 20% tension perpendicular to rolling direction

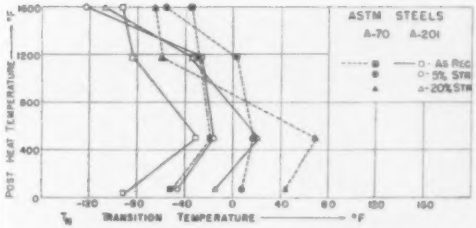

Fig. 19 A-201 and A-70, $^5/_8$-in. steels, as-received and as-strained 20 and 5% parallel to the rolling direction

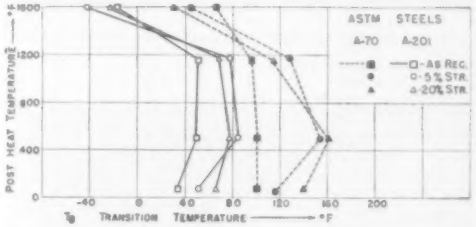

Fig. 20 A-201 and A-70, $^5/_8$-in. steels, as-received and as-strained 20 and 5% parallel to the rolling direction

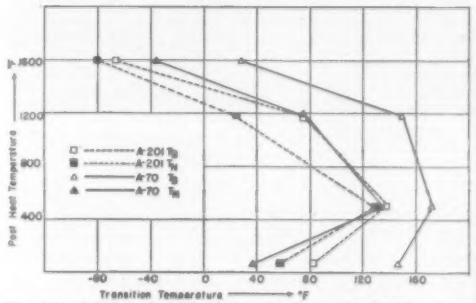

Fig. 21 A-201 and A-70, $^5/_8$-in. steels strained 20% transverse to rolling direction

the T_B transition temperatures.

5% Cylindrically Strained Material

The materials that were cylindrically bent to 5% strain were $1^1/_4$-in. A-70 and A-201 steel. Therefore, to study the effects of 5% cylindrical bending on these steels, the results must be compared with those from 5% axially strained $1^1/_4$-in. material reported in P.V.R C Progress Report No. 3.[3] Such a comparison shows that the transition temperatures T_N and T_B for the cylindrically bent specimens agree within ±15° F. of those from specimens axially strained. Normalizing heat treatment at 1600° F. was omitted in this series to save time and material since its beneficial effect has already been established through earlier tests. Figures 22 and 23 represent the per cent cleavage (T_B) transition curves and Figs. 24 and 25 represent the per

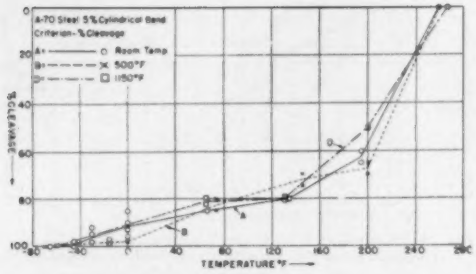

Fig. 22 Transition temperatures showing the effects of heat treatment on 5/8-in. A-70 steel, 5% cylindrical bend

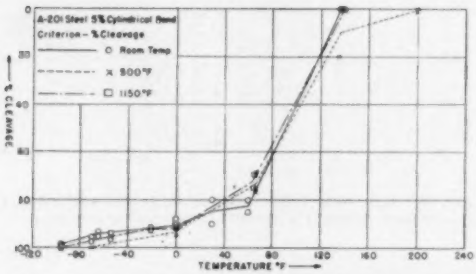

Fig. 23 Transition temperatures showing the effects of heat treatment on 5/8-in. A-201 steel, 5% cylindrical bend

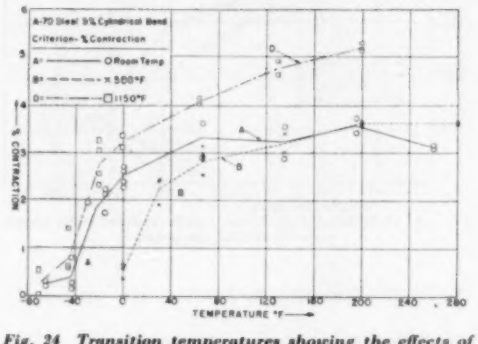

Fig. 24 Transition temperatures showing the effects of heat treatment on 5/8-in. A-70 steel, 5% cylindrical bend

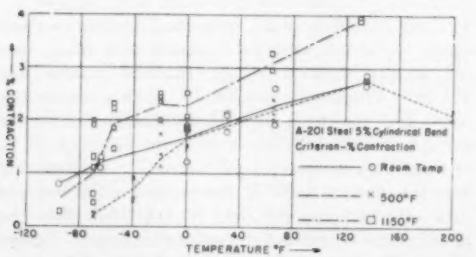

Fig. 25 Transition temperatures showing the effects of heat treatment on 5/8-in. A-201 steel, 5% cylindrical bend

cent contraction (T_N) transition curves of the 5% cylindrically strained materials.

Spherically Pressed Material

In order to be able to determine the effect of spherically forming 5/8-in. A-201 and A-70 steels on their cold brittleness, a new specimen and testing jig had to be developed. Therefore the results of this test series cannot be correlated directly with the other test results.

Unpressed specimens of 5/8-in. A-201 and A-70 steels were tested in duplicate in the spherical testing

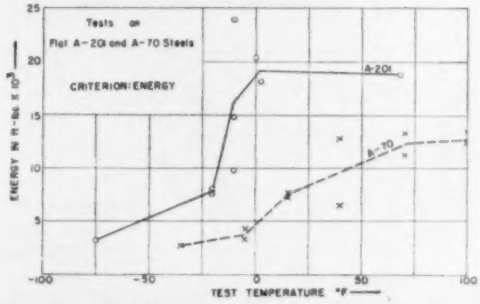

Fig. 26 Transition curves on flat circular specimens showing the relationship between 5/8-in. A-70 and A-201 steels

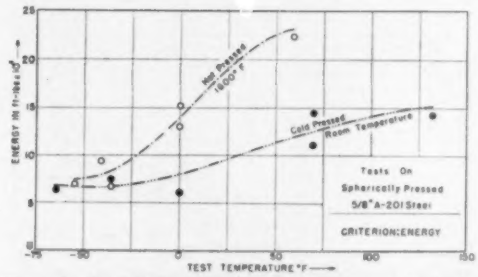

Fig. 27 Transition temperature tests on spherically pressed specimens, with circular V-notch, 5/8-in. A-201 steel; V-notch: 4 1/2 in. diameter, 0.12 in. deep

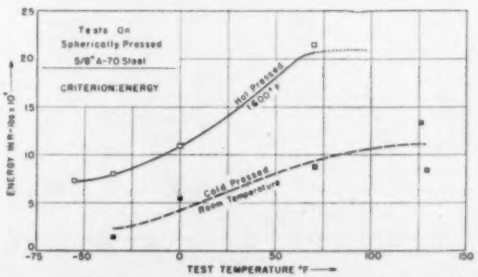

Fig. 28 Transition temperature tests on spherically pressed specimens with circular V-notch, 5/8-in. A-70 steel; V-notch: 4 1/2 in. diameter, 0.12 in. deep

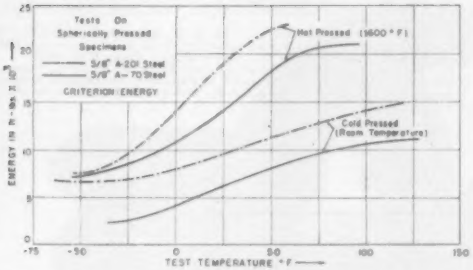

Fig. 29 Transition-temperature curves showing relationship between hot and cold spherically pressed A-201 and A-70 steels

jig to establish their cracking level, Fig. 26. These energy-transition curves differentiate between the two steels. However, the difference between the transition temperatures of these steels is only half as great as that determined by the Lehigh slow-notch-bend test. The difference in the energy absorbing capacity of the steels is brought out quite clearly when one considers the general shape of the transition curves.

In Figs. 27 and 28 are presented the tra.isition curves for A-201 and A-70 steels, respectively, after hot (1600° F.) and cold (room temperature) forming opera tion. Because the number of specimens tested in this series was too few to determine the transition curves with accuracy, best-fitting curves were drawn through the points rather than by joining the averages of the points with straight lines. These curves are superimposed in Fig. 29 to afford a better comparison of the response of the two steels to hot and cold forming. The transition temperatures are given in Table 1, D and E. Cold forming increases the transition temperature of both steels, and the energy-absorbing capacity is reduced considerably. Hot forming, on the other hand, lowers the transition temperature and the energy-absorbing capacity is raised to a level higher than that of the as-received plate. Figures 30 and 31 represent the mode of failure of the spherical specimens. It is interesting to note that brittle fractures always progress into the unnotched steel rather than follow the notch all the way around.

CONCLUSIONS

1. A tensile strain of 20% parallel to rolling raises the ductility transition temperatures of both $^5/_8$-in. A-201 and A-70 steels by approximately 80° F. above the unstrained steel. This is about 35° F. above the transition temperatures of earlier tests given 5% strain.

2. Steels strained 20% transverse to the rolling direction had transition temperatures 130° F. higher than unstrained material.

3. Transition temperatures T_N for both steels, cylindrically strained 5%, agree within experimental error with those 5% axially strained as reported in Progress Report No. 3.

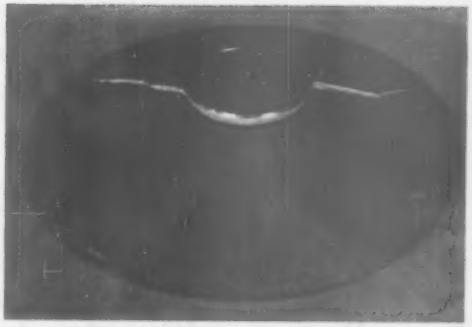

Fig. 30 Spherical specimen showing typical brittle fracture

Fig. 31 Spherical specimens showing typical shear fracture

4. Transition temperature tests on spherically hot- and cold-pressed specimens indicate that cold pressing definitely raises the transition temperature whereas hot pressing results in transition temperatures that are equal to or better than those of the unpressed steels.

ACKNOWLEDGMENTS

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Acknowledgments are also due to Leon Eriv who collaborated on tests of the 20% strained material and to Kenneth Harpel, foreman of the machine shop, and to the entire laboratory staff.

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New German Standards for Testing Welded Joints

by N. Ludwig

IN ORDER to provide uniform standards for testing welded joints, the Welding Committee of the German Standards Association and Committee 10 of the German Welding Society issued on June 13, 1951, a standard on notch impact tests for fusion-welded butt joints (DIN 50122) and four tentative standards:

DIN 50120 Tension tests for fusion-welded butt joints in steel.
DIN 50121 Bend tests for fusion-welded butt joints in steel.
DIN 50126 Tension tests of fillet welds in steel.
DIN 50127 Soundness tests of fusion-welded butt and fillet joints in steel.

Two types of tranverse tensile specimens are described in 50120. The first type is a parallel section specimen for testing the joint as a whole. The second type is a reduced section specimen designed to force failure in the weld metal. The weld re-enforcement is machined flush with the plate surface in both specimens. The tensile strength of the reduced section specimen is calculated on an area 1.1 times the minimum cross section.

The bend test (DIN 50121) is a free bend type, the specimen resting on round bars 2 in. in diameter. The central plunger has a diameter of two or three times the plate thickness. The dimensions of the specimen and the distance between supports varies with plate thickness and with the tensile strength of the plate. For example, for 1-in. plates up to 60,000 psi. the plunger is 2 in. in diameter and the distance between bar centers is $8^3/_8$ in. For 1-in. plates over 60,000 psi. the plunger is 3 in. and the distance between bar centers is $10^3/_8$ in. The clear distance between the bars is always equal to the sum of plunger diameter plus three times the plate thickness. The test is continued until the first "metallic crack" is observed on the tension side. Bend angle and bend elongation in $^3/_4$ and $1^1/_2$ in. are recorded. If the weld is to be hot formed the bend test may be performed at any desired temperature. To detect quench susceptibility the joint may be quenched in water from 1200 F and tested either at once or after 24 hr. aging.

The tension test for fillet welds (DIN 50126) is intended principally to test the welding operator. Either a cruciform or a tranverse fillet specimen may be used. The throat of the fillet must be 0.20 ± 0.04 in. in both specimens.

Three types of soundness specimens are described in DIN 50127. The first type for butt welds is similar to a nick-break specimen except that the nick is a drill hole instead of a saw cut. The second is a simple fillet break test. The third test is for lap welds, the weld being broken by forcing a wedge between the plates.

Abstract of "Neubearbeitete Normblätter über Festigkeitsprufverfahren von Schweisverbindungen," published in *Schweissen und Schneiden*, 3, 288-294 (1951). (Abstracted by Dr. G. E. Claussen.)

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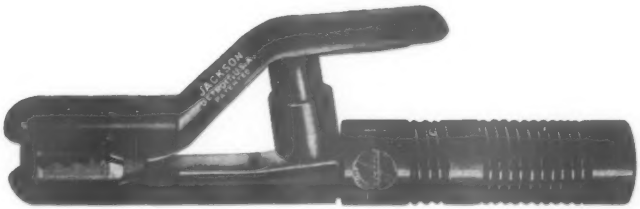

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